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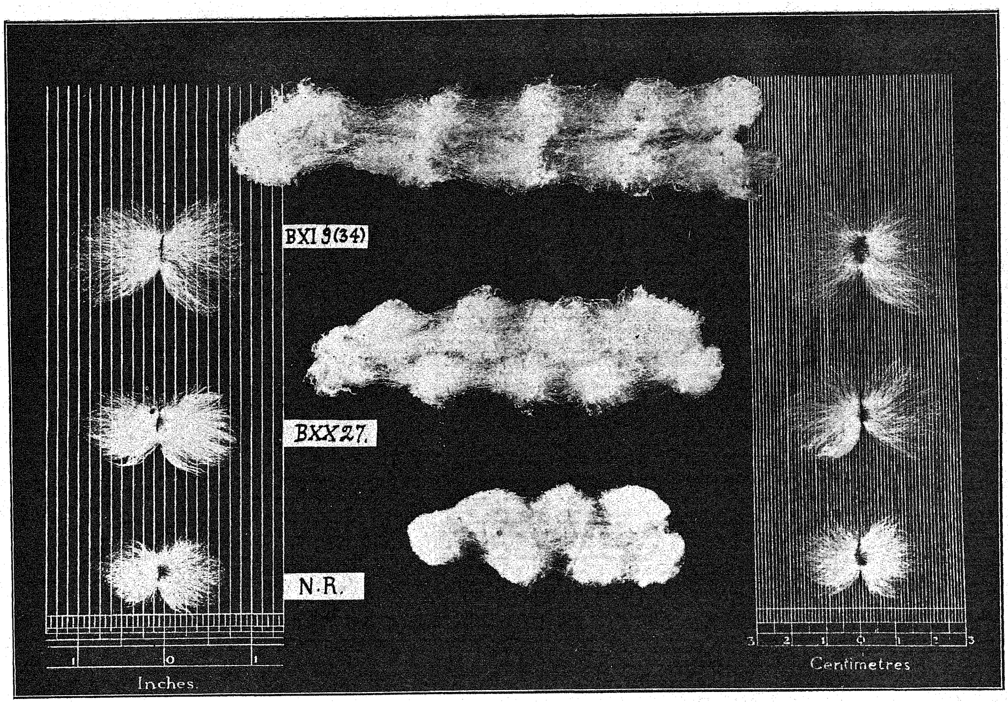
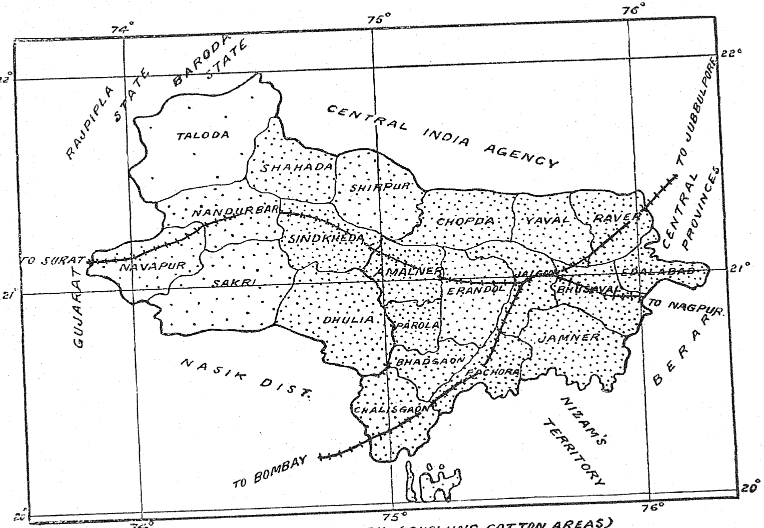


Seeds and staple of lint from improved types of cotton for Khandesh, compared with prevailing type (N. R.)



MAP OF KHANDESH (SHOWING COTTON AREAS)
ONE DOT = 1000 ACRES.

Map of Khandesh, showing intensity of cotton cultivation.

STUDIES IN KHANDESH COTTON, PART I.

BY

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(Received for publication on 19th April 1927.)

I. Introduction.

In the extreme east of the Bombay Presidency lies the very important cotton tract known as Khandesh, forming the south-east extremity of the Oomra cotton producing tract of India. The districts of East and West Khandesh have an area of 9,863 square miles, and are bounded on the south by the Nizam's Dominions, on the north by the Satpura mountains, while on the east they are bordered by Berar, the latter being perhaps the most intensive cotton tract of India and the centre of the production of Oomra cottons.

The central feature of Khandesh is the river Tapti, and the whole district lies in its valley. Its climatic conditions are comparatively simple. The hot weather lasting from March to June is *extremely* hot, the maximum temperature in the shade often reaching 118°F. The monsoon generally begins in June, and is, on the whole, more certain than in most other parts of the Bombay Deccan. The rainfall in the intensive cotton growing parts of the district varies from an average of 20 to 27 inches a year, and commences in June. It is practically over by the end of September and very little reliable rain occurs in October.

The cotton crop is entirely grown on the natural rainfall without irrigation and, in fact, facilities for irrigation do not exist. Therefore, as a result of the very limited distribution of the rain throughout the year, this being only reliable from June to September, the only cotton which can be grown is one which ripens rapidly before the soil dries up after the monsoon rain.

The main feature, agriculturally, therefore of the Khandesh cotton crop is its earliness. It is usually harvested by the end of November with a small supplementary picking a month or so later. The success of the crop, therefore, depends mainly on timely sowing, and the period for this is very limited. The early rains of June are very precarious. Even if they are adequate and satisfactory, the sowing period has to be compressed into between one and two weeks. Very often they are not entirely satisfactory, and then the period during which the land is in suitable condition for cotton sowing is still shorter as was the case in four out of the last six years. Further rain is expected, and is almost certain at the end of June or in

early July, and the seed must be in the ground before this, if a satisfactory crop is to be obtained. Cotton is often sown after this rain is received, but it is recognised as very inferior practice, and there may not be a sufficient long break to allow of work on the black cotton soil of the district. Very often, to avoid delayed sowings, cotton is drilled in the dry soil before the burst of the monsoon. This is a risky procedure. If there is good and timely rain afterwards, good results are obtained; if not, then the crop has to be resown. Generally, July 5th is about the last date on which cotton can be sown successfully. The limitations of rainfall just described seem to determine the kind of cotton grown in this tract. On the whole, East Khandesh is more favourably situated than West Khandesh in the matter of rainfall, while the soils there are deeper and more retentive.

The introduction of cotton into Khandesh as an important crop has been stated to be of relatively recent date. During the time of the Moguls, Khandesh is said to have been a jungle producing wild elephants in abundance.[1] During the British period, cotton cultivation has, however, spread to such an extent that it is the most important crop in the districts, occupying more area than any, even, of the food crops. In 1924-25, the cotton area amounted to 1,303,192 acres and in 1925-26 to 1,394,674 acres. In the latter year this amounted to 40·5 per cent. of the *nett* cropped area. The proportion in East Khandesh is even higher, being 43·3 per cent. of the nett cropped area.

Commercially, as has already been stated, the cotton grown in this part of Western India falls under the great group of "Oomras", a name derived from Amraoti, the capital of Berar. Khandesh cotton amounts to from 11 to $12\frac{1}{2}$ per cent. of the whole "Oomra" crop.

II. The Botanical Characters of Khandesh Cotton.

By far the predominating constituent of the mixture of cotton which constitute the ordinary crop grown in Khandesh is *Gossypium neglectum* (Tod). Within this single species, however, a large number of forms exist, distinguished by leaf and flower characters. Before, however, an attempt is made to describe these, it may be desirable to study the other types which are found mixed in Khandesh cotton. These are, (1) *Gossypium indicum*, the so-called *Bani* type and (2) *Gossypium hirsutum*, American cotton probably brought to Khandesh from Dharwar and forming the relics of an attempt to introduce long stapled exotic cottons.

Gossypium indicum, Lamk, Bani, Hinganghat or Ghat kapas. This cotton, which is much finer than ordinary Khandesh cotton and has been grown from time immemorial in the Godavari valley, has probably long been found in places in Khandesh, but in the year 1865 a very big attempt was made to extend its cultivation. 1,717 tons of seed were then brought from Berar and were used to replace more than

[1] *Empire Cotton Growing Review*, Vol. II, No. 4 (October 1925).

69 per cent. of the local crop.[1] In 1867, Mr. Ashburner, the Collector of Khandesh, took vigorous steps to popularise this cotton, with the idea of substituting it entirely for thelocal coarse and short stapled type. In March 1867 Rs. 20,000 and in April Rs. 50,000 were spent by Government in purchasing Hinganghat seed, and for the time being the old cotton seemed almost entirely replaced. In 1869-70 in some parts of the district, the old local cotton reappeared, but by distributing new Hinganghat seed, a further attempt was made to prevent the reappearance of the former. Owing, however, to the low yield and low ginning percentage of the *bani* cotton, its cultivation began to decline markedly after 1873, and the local cotton gradually replaced it again.

Bani cotton gives probably the best lint of any truly Indian cotton[2]. Its staple is strong, silky and up to one inch staple or a little more. Unfortunately, its ginning percentage is very low, and this seems mainly responsible for its disappearance. Its characters, as the typical example of *Gossypium indicum*, have been often described.[3] It so closely, however, resembles *Gossypium neglectum malvensis* that it is extremely difficult to separate the two except by the staple characters. The difference in the length of the lint is sufficient distinction. It may be noted, however, that *Bani* is somewhat later ripening than the cottons of the "*neglectum*" group and the plants are not so hardy.

The extent to which *bani* is now mixed with cotton as grown in Khandesh varies somewhat, but is everywhere very small. A careful test at Dhulia with average Khandesh cotton gave only 0·55 per cent. of the total plants as belonging to this species.

Gossypium hirsutum, Mill. The other species of cotton found mixed with the neglectum type of Khandesh is American upland, *Gossypium hirsutum.* It appears to be a remnant of old attempts to introduce American cotton in Khandesh since 1846, and to a limited extent its growth may now be said to be naturalised in this tract. Its broad lobed leaves, pale yellow flowers without an eye in the centre, and its low and bushy habit of growth distinguish it at once from the plants with which it is mixed. Its history, so far as it can be made out, is interesting.

The first attempt made to introduce American cotton in Khandesh was apparently in 1846[4] when Mr. Simpson, Superintendent of Cotton Experiments in Gujarat and Khandesh, arranged with cultivators that in Erandol and Nasirabad (East Khandesh), on condition of the remission of land revenue and payment of Rs. 5 per bigha by Government, New Orleans cotton should be grown on 99 acres. The seed was procured from Dharwar, but it was a season of heavy rainfall, the cotton did not flourish and only yielded 220 lb. of clean cotton altogether. It was reported to be inferior to the local cotton both in length of staple and strength. No further attempts at its

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[1] Gammie, Indian Cottons, 1905.
[2] *Empire Cotton Growing Review*, Vol. II (1925).
[3] Gammie, Indian Cottons, 1905.
[4] W. R. Cassels. Cotton: An account of its cultivation in the Bombay Presidency, 1862.

introduction were made at that time, but after small experiments, a further lot of Dharwar American seed was obtained in 1848-49 and 166 acres were planted by various cultivators. This year the cotton suffered badly from drought, and the crop was a poor one. In the following year, again, the area went up to 1,926 acres, but a large part of this suffered from excessive rain. In spite of this, the area went up to 5,272 acres in 1850-51 when most of the seed was planted before the rains came. It flourished exceedingly in the early stages, but the crop was disappointingly small. The Collector (Mr. Elphinstone) wrote in March 1851 : "Hitherto the New Orleans crop has been precarious, and even if, in case of failure, Government excuses the rental, the cultivator has still lost time, labour and profit."

Every effort was made still to push American cotton in Khandesh and prizes were offered for the largest area, and the largest yield per acre. In 1851 the area rose to 10,214 acres, but a drought after the end of August proved far more injurious to this than to the local cotton. As a result, the area in 1852 fell to 4,022 acres, and the officials came to the conclusion that "the soil and climate are not suited to the growth of Dharwar American cotton" and this was agreed to by the cotton trade. In 1852 the crop was only grown on 1,272 acres, and in the following year the area dwindled to 12 acres. The whole effort had been a failure, the cultivators objected to it on the score of its uncertainty, and the Collector (Mr. Mansfield) stated that he was convinced that "the dryness of the climate is an insuperable barrier to the cultivation of New Orleans cotton in this province."

From this time onwards no effort has been made by Government to push the growth of American cotton in Khandesh. But after the failure of the attempts with *bani* cotton, it was taken up again by some growers in 1873, who were attracted by it as giving a good staple and a much higher ginning percentage than Hinganghat cotton. To-day it exists as an admixture almost all over. Tests made at Dhulia and Chalisgaon in 1907 showed that the ordinary field cotton grown contained respectively 2 per cent. and 1 per cent. of American cotton in these two centres. It does well in years of good rainfall. Its yield, however, is not high to compete with the local cottons and it is not likely to replace the indigenous forms to any considerable extent.

In addition to the species mentioned above, it may be noted that there is a limited area of *Gossypium herbaceum* of the Gujarat types grown within the limits of Khandesh. Its cultivation is, however, limited to the extreme west of the area, in the Navapur, Taloda and Nandurbar Talukas of West Khandesh.

Gossypium neglectum, Tod. By far the greater part of Khandesh cotton consists, however, of *Gossypium neglectum*, which is the chief cultivated cotton not only of Khandesh, but also of Berar, the Central Provinces, Central India, the United Provinces, the Punjab and Sind, except where in the last two named provinces it has been recently replaced by American. It forms the main constituent of "Oomras" and "Bengals." In recent years it was extended into new areas such as Kathiawar (especially Bhavnagar) where it is known as *Mathio*.

Botanically, the classification of this type has been somewhat uncertain. Watt[1] classifies it as a variety of *Gossypium arboreum*, Linn. Middleton[2] and Gammie[3] recognise it as a separate species of *Gossypium* and this is retained in the present paper.

The various varieties of cotton classified under the species *Gossypium neglectum* are known in Khandesh and the Berars by the name *Varhadi* and *Jari*. The former name is usually given to cottons having white flowers and the latter to cottons having yellow flowers. It has been suggested[4] that *Varhadi* is the result of a cross between *Gossypium indicum* and *Gossypium cernuum* or Garo Hill cotton. There is no evidence whatever of this. The *Jari* cotton has been supposed[5] to be a degenerate form of a cross between *Bani* cotton and *Gossypium arboreum*, but there is likewise no evidence whatever of this.

These cottons have generally two characters which set them apart from others. These are (1) a short growing period, as compared with other cultivated species. In normal years the cotton is sown in the middle of June. The first picking commences before the end of October and the final picking is taken before January. The white flowered varieties are earlier, in general, than the yellow flowered types (2) a more erect habit than other species of cotton. This allows of thick sowing and gives a high yield per acre.

The botanical characters have been described in detail by Gammie[3] as follows :—

" *Gossypium neglectum*, Todaro, *Osser sui cotoni*, p. 35 (1863). *G. herbaceum*, Linn. Var. *hirsutum*, *Masters* in *Herb. Kew. G. arboreum*, Linn (in part) *Fl. Br. Ind.* I, 347. Plants varying in height from 3 to 7 and more feet. Stems simple, wand-like, tapering gradually from base to apex, bark brown, tessellated, quite glabrous below; with simple, white short deciduous hairs above, herbaceous parts brownish red, specially so on the southern side. Lower branches sparse, long, spreading, medial short, uppermost very short; whole plant usually nodding if well covered with fruit. Leaves palmate or palmatipartite, lobes 3 to 5 or more, oblong lanceolate, ovate acute or sub-obtuse, sinuses broad or rising up into small extra lobes, base shallowly cordate; glands either altogether absent or present on the central rib or faintly present on the three central ribs; stipules lanceolate falcate acuminate or broad ovate few toothed at the apex. Flowers one from each node of the lateral branches, peduncles erect but drooping in fruit. Bracteoles deeply cordate, ovate acute, quite entire towards apex or sometimes toothed there. Calyx cup-shaped, entire or very shortly lobed, Corolla a little longer than the bracteoles, upper part of petals reflexed; filaments comparatively long; stigmas 3-grooved, scarcely rising above the upper anthers, channels with or without black dots. Bolls ovate, obtusely pointed, invested at base by the ruptured enlarged calyx,

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[1] Watt. Wild and cultivated cotton of the world, page 95 (1907).
[2] Middleton. *Agricultural Ledger*, 1895, No. 8, page 11.
[3] Gammie. *Loc. cit.*
[4] Watt. Wild and cultivated cottons of the world, page 133.
[5] Middleton. *Agricultural Ledger*, 1895, No. 8, page 12.

3-4 celled, very distinctly black dotted, valves separating and recurved when ripe. Cotton harsh, clinging more or less firmly to the seed, which is covered by grey velvet."

The individuals constituting this *neglectum* group have been arranged by Gammie in five sub-species as follows :—

(*a*) *Gossypium neglectum*, Tod. var. *vera*.
(*b*) do. do. var. *vera* sub. var. *malvensis*.
(*c*) do. do. var. *vera* sub. var. *kathiawarensis*.
(*d*) do. do. var. *rosea*.
(*e*) do. do. var. *rosea* sub. var. *cutchica*.

Of these, the first three bear yellow flowers, the last two bear white flowers. The yellow flower varieties are distinguished by the lobing of the leaves. The first (var. *vera*) has more deeply lobed leaves than the other two. The second (var. *malvensis*) has broader lobed leaves than the third (var. *kathiawarensis*). The white flowered varieties are also distinguished by the leaf lobing, the variety *rosea* having deep narrow lobes undistinguishable from those of the variety *vera*, while the variety *rosea cutchica* has broad lobes in the leaf, like those of the variety *vera malvensis*.

This classification has been adhered to in the present memoir, but it may be noted that Watt[1] has classed the variety *rosea* (also known as N. R. cotton) as a separate variety of *Gossypium arboreum*. Middleton[2] places it as a separate species of *Gossypium*. A close study of the types in the field inclines the author to the view that there is no justification for separating it from the *neglectum* cottons.

EXTENT OF ADMIXTURE OF VARIETIES IN KHANDESH COTTON. Whatever may have been the source of the various constituents of the mixture of varieties now occurring in Khandesh cotton, the fact is certain that they all occur in the cotton as now grown. The extent to which they occur was investigated in 1906, 1907 and 1911. In 1906[3] a field of one acre of cotton from seed procured at Dhulia gave the following results :—

Variety	Plants per acre	Percentage composition
Gossypium neglectum—		
(*a*) var. *vera*	1,190	3·5
(*b*) var. *vera malvensis*	200	0·6
(*c*) var. *vera kathiawarensis*	5,190	15·2
(*d*) var *rosea*	12,850	37·8
(*e*) var. *rosea cutchica*	14,320	42·1
Gossypium indicum (*Bani*)	190	0·6

[1] Watt. *Loc. cit.*
[2] Middleton. *Loc. cit.*
[3] *Dhulia Agri. Station Ann. Rep.*, 1906-07, page 7.

From 1908 to 1910 bazar samples of cotton seed were obtained from every taluka in Khandesh. As a result of row cultures of these samples, the following average proportion in the mixture was determined[1] :—

Variety	Percentage composition
Gossypium neglectum—	
(*a*) all *vera* types	25·8
(*b*) var. *rosea*	46·6
(*c*) var. *rosea cutchica*	27·6

The conclusions drawn from the three years' study were as follows :—

1. The proportion of white flowered plants is much higher in East Khandesh than in West Khandesh, where it is lowest in the talukas of Nandurbar, Shahada and Taloda.
2. Those talukas of West Khandesh which are adjacent to East Khandesh have the largest proportion of white flowered plants.
3. In East Khandesh, the white flowered types are more prevalent in the north than in the south.
4. Among white flowered types, the proportion of the variety *rosea* (N. R.) is greatest in Amalner and Bhusawal, and in East Khandesh is lowest in Chalisgaon, Pachora, Bhadgaon and Erandol.
5. In West Khandesh, the proportion of var. *rosea cutchica* is greatest in the northern talukas. In the other talukas the two white flowered varieties are in almost equal proportion.
6. Navapur, which is situated near Gujarat, grows pure *herbaceum* cotton.

Trials of different constituents of Khandesh cotton. Having thus ascertained the proportion of the various constituents of the mixture grown in Khandesh, the yield of seed cotton which each of these varieties will give was determined at Dhulia in the years from 1906-1914, together with the ginning percentage. The consolidated results are as follows :—

Variety	Yield seed cotton per acre. lb.	Ginning percentage Per cent.
(*a*) *vera*	531 (average of 4 years).	28·6 (average of 8 years)
(*b*) *vera malvensis*	485 „ 3 „ .	24·8 „ „
(*c*) *vera kathiawarensis*	560 „ 2 „ .	26·5 „ „
(*d*) *rosea* (N. R.)	895 „ 5 „ .	36·4 „ „
(*e*) *rosea cutchica*	806 „ 5 „ .	34·9 „ „

[1] *Dhulia Agri. Station Ann. Rep.*, 1911-12, page 3.

The results indicate that, so far as the strains occurring in cultivation are concerned, the white flowered varieties are the prolific yielders, in addition to their superiority in ginning percentage. Even in any unfavourable season like 1912-13 the superior yielding capacity of the white flowered types was quite evident.

A more extended trial of three of the above varieties was made at Jalgaon in 1918 and 1919. It must be remembered that 1918 was an exceedingly dry season.

Yield and ginning percentage of Khandesh cotton varieties, 1918-19.

Variety	Average yield seed cotton per acre	Average ginning percentage	Valuation of lint per Candy 1919-20 *	Lint value per acre
	lb.		Rs.	Rs.
(a) *vera*	342	32·5	425	59·6
(b) *vera malvensis* . . .	344	30·9	425	57·5
(c) *rosea* (N. R.)	536	37·2	320	81·2

* The basis of valuation in 1920 was Oomras Rs. 425, Khandesh Rs. 375 and Broach Rs. 520, per candy of 784 lb.

It is interesting to compare with similar tests made in these varieties as separated from the *neglectum* mixtures in the Central Provinces. The following results were published there in 1912.[1]

Variety	Average yield for four years			Ginning percentage
	Seed cotton	Lint	Seed	
	lb.	lb.	lb.	
(a) *vera*	344	116	228	33
(b) *vera malvensis* . . .	374	112	262	30
(c) *rosea* (N. R.) . . .	402	162	240	40
(d) *rosea cutchica* . . .	412	150	262	37
(e) *Bani*	252	72	180	28

From all these tests the following salient facts emerge :—

1. The variety *rosea* (N. R. cotton) has given the highest outturn consistently as compared with other varieties.
2. The variety *rosea* (N. R. cotton) has had a substantial advantage in ginning percentage which has secured a higher price for seed cotton (*kapas*) in the market.

[1] *Agricultural Journal and Co-operative Gazette,* Central Provinces, June 1912.

3. The nett profit per acre has been strikingly superior in the case of the variety *rosea* (N. R. cotton).
4. The variety *rosea* (N. R. cotton) has been found to be more drought resistant, a quality of great importance in the Khandesh tract.
5. The variety *rosea* (N. R. cotton) opens its bolls well and uniformly and it is earlier than the yellow flowered varieties.

These several advantages of the variety *rosea* (N. R. cotton) occurring in the *neglectum* mixture as it grows in Khandesh, were so great that, in spite of its poor staple, and hence the lower price of the lint on the market, when its seed was supplied pure, it was welcomed heartily by the more progressive cultivators of these districts, and its use has been extending ever since. The Bombay Agricultural Department has, in fact, been itself distributing seed of this variety of guaranteed purity for 30,000 acres a year for some time. But in the meantime alarm has been created that its wider extension may mean a further lowering of the standard of Khandesh cotton, for the staple of the *rosea* variety (N. R. cotton) is not more than half an inch. Further, the lint was considered to be extremely coarse and its spinning capacity only reached to "8's."

ATTEMPTS AT THE IMPROVEMENT OF STAPLE IN KHANDESH COTTON. The question of obtaining a better quality cotton without necessarily sacrificing anything in point of yield came, therefore, to the front, and this is not for the first time, and in a few words an account may be given of these previous, if unsuccessful, efforts.

Khandesh was one of the earliest tracts selected by Government for the trial of cotton of long staple. The first attempt dates from 1831, when carefully picked cotton, chiefly from the north-east talukas, was distributed over the rest of the district. In 1833 seed of Egyptian, Bourbon and Pernambuco seed from an experimental farm at Broach, and in 1834 two parcels of Pernambuco and Bahia seed, were sent to the Collector of Khandesh for experiment. In 1836 no less than 14 tons of the best Broach seed were sent to Khandesh for trial, and for a time the results appeared to be encouraging, but the attempt to acclimatise Broach cotton ultimately failed. The later unsuccessful trial with New Orleans cotton, and with *Bani* cotton, has already been described (pp. 2—4).

The last important attempt at the acclimatisation of introduced good staple varieties took place in the years following 1904. At that time, in response to an appeal from the British Cotton Growing Association, both indigenous and exotic varieties of both annual and perennial type were tried at the Dhulia farm. The number of such varieties tested in 1908 was twenty-four. Of these *Cambodia* and *Buri* varieties at first appeared to be successful. These retained vigorous growth longer than the other types tried, but even with them, the absence of late rains made their yield extremely precarious. The perennial cottons tried included Bourbon and 'Rough Peruvian.' The former grew fairly well, the plants reaching a uniform height of two feet, and giving a yield of four ounces of seed cotton per plant. But

the general result was that the season was too short for such cottons and the experiment had to be abandoned.

The results on the whole may be summarised as follows :—

(*a*) The cotton all matured later than the local types, generally the first picking coincided with the second picking of the local variety. This lateness is fatal in Khandesh.

(*b*) The ginning percentage is in nearly all cases considerably lower than the local types and prevented their competition with the *rosea* variety (N. R. cotton) if not with other local types.

(*c*) The yield per acre was, in nearly every case, lower than with the *rosea* variety (N. R. cotton) if not with other local types.

(*d*) Most of the American varieties proved very susceptible to red leaf blight under Khandesh conditions.

These results, though negative, are very important and brought us up face to face with what are apparently the only other two methods of obtaining a cotton with all the desirable qualities of the *rosea* variety (N. R. cotton) but with a superior staple. These two methods, both based essentially rather on the improvement of existing local material in cultivation, are (1) the pursuance of a rigid system of selection in *neglectum* cottons now grown in Khandesh, in the surrounding areas, or even in other parts of India, and (2) the development of new types with the desired qualities suited to this region, by crossing types whose combination seemed to show probability of the isolation of a suitable strain for the purpose in view. The results of work on these lines, which was initiated in 1921, are embodied in the present memoir.

III. Improvement of Khandesh Cotton by Selection.

The material used in the selection studies consisted, first and foremost, of strains isolated from local material especially of the *rosea* variety, secondly of a collection of cottons made in Berar and Central India, and thirdly of *neglectum* cottons isolated on other farms either in the Bombay Presidency (big bolled N. R., and *rosea* from Dharwar, black seeded N. R. from Surat) or in other provinces (J. N. I and K. 22 from Cawnpore). For the first time in work on these Khandesh cottons the methods of pure line cultures were adopted and selfed seed was used throughout. The method of selfing adopted was that devised by Kottur which consists of putting small rings on to the flower buds so that the petals do not open.

VARIATION IN THE DIFFERENT VARIETIES OF NEGLECTUM COTTONS. During the work it quickly became evident that in no case was the botanical variety, as considered hitherto, genetically pure. The characters to which special attention was directed were as follows :—

(1) The branching habit of the plant, (2) the point of origin of the first primary fruiting branch (*sympodium*), (3) the ginning percentage of the seed cotton, (4) the staple of the lint, (5) the glands on the leaves and

(6) the dimensions of the petals. In no case did the botanical varieties, as illustrated by one hundred plants, remain constant or give progeny with the same range of variation from generation to generation.

The variation with regard to these items will be considered in detail, so far as the *rosea* variety (N. R. cotton) is concerned.

1. *The branching habit of the plant.* The importance of this character has been emphasised by previous workers. Kottur [1] in his study of Kumpta cotton has isolated bushy and erect types of *Gossypium herbaceum* as grown in the south of the Bombay Presidency. Similar results have been obtained by Patel.[2] Leake [3] considered that it is one of the fundamental differences between different types of cotton and bases his classification of cotton to a considerable extent on the frequency of the occurrences of and the number of monopodia or, in other words, on the branching habit.

All the *neglectum* cottons are of a very erect habit as compared with most other species, and in particular with the types of *Gossypium herbaceum* and may be said to be sympodial in character. The number of primary monopodia, however, varies from one to five.

The general variation within the *rosea* type (N. R. cotton) as grown in Khandesh is shown by the following frequences of different numbers of monopodia in about one hundred plants in four successive years, as shown in the following Table.

Number of monopodia in the rosea variety.

Number of monopodia	Frequency of occurrence					
	1922-23		1924-25		1925-26	
0	8	8·9	13	14·4	7	5·7
1	21	23·3	22	24·4	23	18·6
2	*30*	33·3	*27*	30·0	*36*	29·0
3	21	23·3	15	16·7	34	27.4
4	6	6·7	5	5·6	21	16·9
5	4	4·5	5	5·6	3	2.4
6	..	..	3	3·3	..	..
Total number .	90	100	90	100	124	100

[1] Kottur, G. L. Kumpta cotton and its improvement. *Mem. Dep. Agri. India, Bot. Ser.*, Vol. X, No. 6 (1920.)

[2] Patel, M. L. Studies in Gujarat Cottons II. *Mem. Dep. Agri. India, Bot. Ser.*, Vol. XII, No. 5 (1924).

[3] Leake, H. M. *Agri. Journal of India*, Vol. X. page 116 (1915).

These results are illustrated in Fig 1.

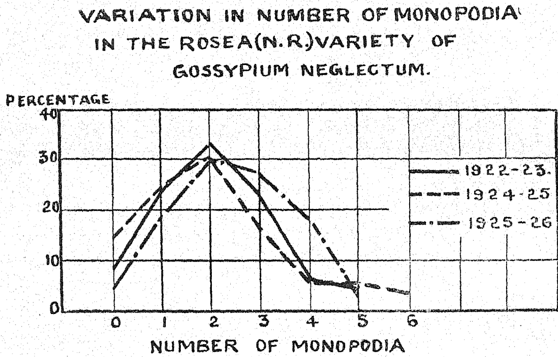


FIG. 1.

2. *The point of origin of the first primary fruiting branch.* The importance of this character has been emphasised by Patel [1] in his studies of the Gujarat cottons, and it determines considerably the type of plant in the field. The positon is determined by the *node* on the stem from which the first primary fruiting branch arises. The variation even in *rosea* type (N. R. cotton) alone is very considerable, as is illustrated by the following figures from a series of plants of this variety grown at Dhulia.

Position of the first primary fruiting branch. Frequency of occurrence.

Node of origin	1922-23	1923-24	1924-25	1925-26
7th	..	3	2	1
8th	4	4	1	2
9th	14	32	12	17
10th	*31*	*35*	27	26
11th	29	15	*33*	*34*
12th	12	6	19	32
13th	5	3	7	8
14th	..	..	2	5
Total number of plants	95	98	103	125

[1] *Loc. cit.*

The results show a good deal of variation not only in the same season but from year to year. In this connection a note of Patel (who has made the most careful study of this character) may be kept in view. He says " The variation in one and the same season in a pure strain is fairly wide and different plants growing under identical conditions vary by six to eight nodes. But the relative difference in the nodal value is maintained."

3. *Ginning percentage of the seed cotton.* The high reputation that the *rosea* variety (N. R. cotton) claims is due mainly to its high ginning percentage. Recently, however, there has been a tendency for this high percentage to go down. The records at the Jalgaon farm, for over 30 acres of this cotton grown quite pure for the last eight years, show this tendency clearly.

Year	Ginning percentage of N. R. cotton at Jalgaon Per cent.
1918	37·5
1919	37·5
1920	35·2
1921	35·9
1922	33·4 to 36·2
1923	37·1
1924	35·0 to 41·2
1925	31·2 to 34·5

The variations between different plants in this variety in three successive years were as follows :—From eighty-five to one hundred and twenty-three plants were examined in the several years, and the plants were grown at Dhulia.

Ginning percentage of N. R. cotton at Dhulia.

Ginning percentage	Frequency of occurrence					
	1923-24		1924-25		1925-26	
Under 27	1	1·1	..	..	..	..
27 to 29	4	4·3	6	7·0	2	1·6
29 to 31	4	4·3	9	10·6	6	4·9
31 to 33	10	10·7	17	20·0	14	11·4
33 to 35	17	18·3	8	9·4	31	25·2
35 to 37	15	16·1	20	23·5	34	27·6
37 to 39	25	26·9	14	16·5	23	18·7
39 to 41	16	17·2	11	13·0	9	7·3
41 to 43	1	1.1	..	..	4	3·3
	93	100	85	100	123	100

A curve embodying these results is shown in Fig. 2.

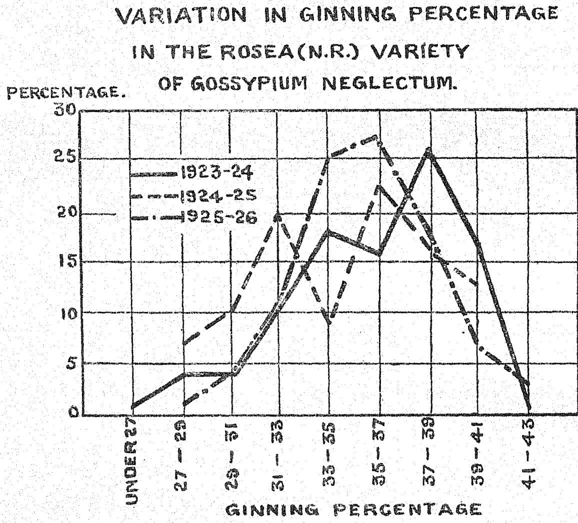


FIG. 2.

Though it is evident that ginning percentage (being a ratio between two independent variable) is a somewhat complicated conception, yet there is little doubt from these figures of the existence of a number of strains with different relationships of the quantity of lint to the seed weight.

4. *The staple of the lint.* The *rosea* variety (N. R. cotton) is very inferior in staple, the latter varying from 10 to 15 mm. and going upto 17 mm. in extreme cases. The method adopted in measuring the staples in these variation studies was that recommended by Balls[1] and consisted in combing out the lint on the seed and measuring the maximum length from the seed to the edge of the halo along a radius.

The following figures illustrate the variation in the staple in about one hundred plants in each year since 1921-22. (Fig. 3.)

[1] The development and properties of raw cotton, 1915.

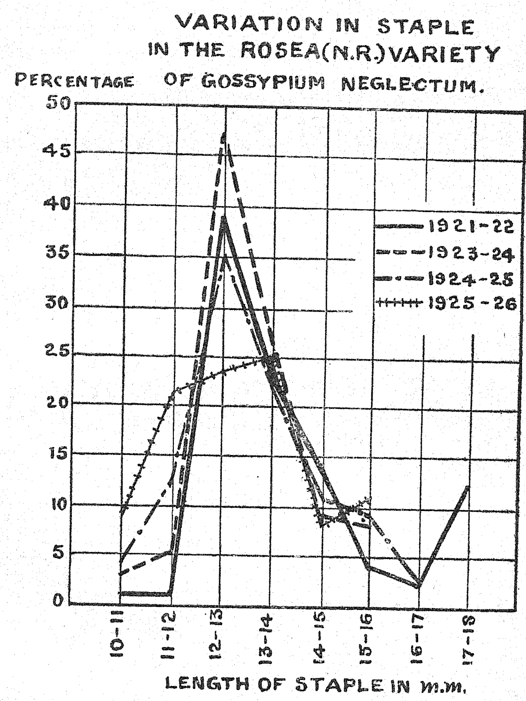

VARIATION IN STAPLE
IN THE ROSEA(N.R.)VARIETY
PERCENTAGE OF GOSSYPIUM NEGLECTUM.
50
45
40
35
30
25
20
15
10
5
0
1921-22
1923-24
1924-25
1925-26
10-11
11-12
12-13
13-14
14-15
15-16
16-17
17-18
LENGTH OF STAPLE IN m.m.

Fig. 3.

Staples of N. R. cotton.

Length of staple mm.	Frequency of Occurrence.							
	N. R. 1921-22		N. R. 1923-24		N. R. 1924-25		N. R. 1925-26	
10—11	1	1·1	3	3·1	4	4·9	12	9·8
11—12	1	1·1	5	5·2	11	12·8	26	21·1
12—13	*35*	39·8	*46*	47·9	*3*	35·3	29	23·6
13—14	21	23·9	25	26·1	19	22·3	*31*	25·2
14—15	13	14·8	9	9·4	10	11·8	11	8·9
15—16	4	4·5	8	8·3	8	9·4	14	11·4
16—17	2	2·3	..	..	3	3·5	..	..
17—18	11	12·5	..	..	..	..	..	..
	88	100	96	100	85	100	123	100

A similar study of the *vera* variety of *Gossypium neglectum* (page 6) as grown in Khandesh in 1921-22 showed variation as indicated in the following Table :—

Length of the staple, mm.	Staple of N. V. cotton. Frequency of occurrence. 1921-22
11·12	2
12·13	4
13·14	3
14·15	34
15·16	24
16·17	14
17·18	11
18·19	8
19·20	1
	101

The variations in both cases are such as to suggest a mixture of several strains.

5. *The glands on the leaves.* Another character which has been found useful in the separation of the strains in the *rosea* variety (N. R. cotton) is the glands on

the leaves. These are usually three in number and they are situated in the three midribs at the back of the leaf. The number of such leaf glands on plants of each of the varieties of *neglectum* cotton is very variable. In some cases, the glands are entirely absent. The following figures represent the result of the examination of eighty plants in 1921-22 :—

Number of plants examined	80
Number with uni-glandular leaves	32
Number with tri-glandular leaves	24
Number with a-glandular leaves—(no glands)	24

Two types with no glands were selected, and these have maintained this character in succeeding generations. Further work in this direction has not been undertaken.

The study of the few characters noted above, continued in the case of the first four for a period of four years, clearly indicates that the *rosea* variety (N. R. cotton), at any rate, is a mixture of a number of strains varying in botanical and also in commercial characters. Some of these types have been isolated and now breed true to their special characters. These will now be described as representative types of the *rosea* variety (N. R. cotton).

Description of types isolated from Gossypium neglectum var. rosea (N. R. cotton) as grown in Khandesh.

1. *Pimpalgaon.*

This is a strain which has been isolated from material collected at the village of Pimpalgaon (Pachora Taluka, East Khandesh). The seed from which it was obtained had the reputation of giving a very high ginning percentage. The characteristics of the strain are as follows :—

(*a*) The leaves are of the typical *rosea* type.

(*b*) The plants bear a higher number of monopodia than is usual with the *rosea* variety, the number varying from 1 to 6. It may, therefore, be considered as a bushy type (Plate IV).

(*c*) The bolls are large and oval with a marked point at the tip (Plate VIII).

(*d*) The flower petals emerge beyond the bracts. This is unusual with N. R. cotton, where the petals are generally completely enclosed in the bracts.

(*e*) The ginning percentage for which character the strain was selected has been as follows :—

Year	Ginning percentage
1923	$40{\cdot}2 \pm 0{\cdot}07$
1924	$42{\cdot}2 \pm 0{\cdot}25$
1925	$37{\cdot}6 \pm 0{\cdot}11$

(*f*) The weak point of this strain is its yield and it does not compare with that from the mixture of strains of the *rosea* variety known as N. R. cotton. The yield in lines of 100 plants in three successive years is as follows :—

Mean yield of seed cotton per plant.

—	Pimpalgaon	N. R. cotton
	grm.	grm.
1923	47·6	41·5
1924	32·7	45·3
1925	28·5	35·3

In two replicates in 1925 at Dhulia, it gave 10·7 per cent. less yield than N. R. cotton. The replicate tests were done in the following manner. Each strain was sown in four lines each one hundred feet long alternated by four lines of N. R. cotton. The number of such replicates tried was five in each strain. The first and the fourth row of each series were rejected in yield tests to avoid any possibility of competition between strains, the middle two rows only being compared with those of the check plot. The interpretation of results was done according to the method suggested by Sircar (*Agri. Jour. India*. Vol. XVIII, September 1923).

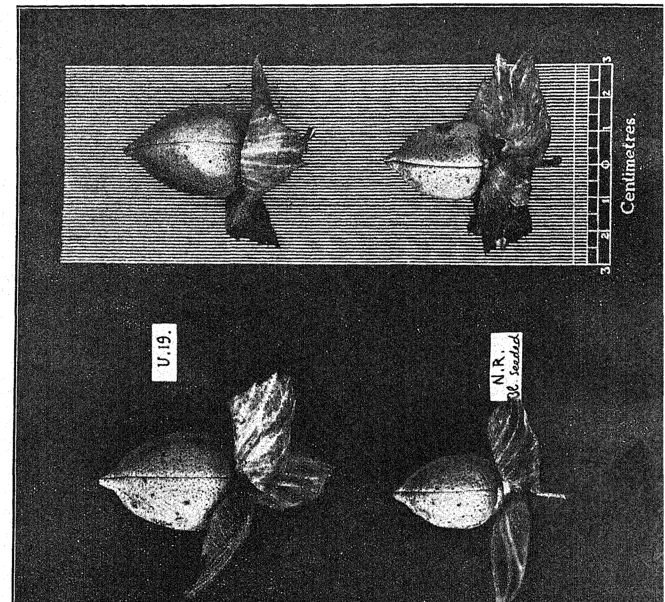
2. *U-29.*

This strain was selected on account of high ginning percentage and has been maintained largely because it has characteristic leaves which render it easily identified. The leaves, in fact, bear no accessory lobes at all, and it is thus different from all other strains of N. R. cotton. The plant possesses no other special features, but the yield of seed cotton, ginning percentage, and staple of the pure strain have been as follows, in two successive years. The figures are on the basis of 100 plants.

Characters of strain No. U-29.

—	U-29		N. R. cotton	
	1924	1925	1924	1925
Mean yield per plant in gram. .	41·0	26·8	45·3	35·3
Ginning pecentage . . .	42·9	39·4	34·7	35·8
Staple in mm.	14·5	15·4	12·7	12·1

PLATE III.



In 1925 this strain was tried in a series of two row replicates with N. R. cotton with the following results :—

Yield of seed cotton in replicates 1926.

Replication	U-29	N. R. cotton
	lb.	lb.
1	4·8	5·4
2	4·5	3·3
3	4·0	4·9
4	4·7	4·2
5	4·7	5·8

The mean difference was 7·2 per cent. in favour of the mixture known as N. R. cotton.

On the whole, therefore, this strain may be considered as a high ginning type with a staple slightly superior to that of N. R. cotton. The lower yield renders it useless as it is, but it is maintained as possible material for future crossing.

3. U.-19.

This strain was selected prior to 1921, and has now been bred pure from selfed seed for several years. It has the following characteristics :—

(*a*) The bolls are as large as in the strain Pimpalgaon, although in shape they are more elongated and do not so abruptly terminate at the stigmatic end as in the latter variety. (Plate III).

(*b*) The ginning percentage of the seed cotton in two years was as follows :—

Ginning percentage of U.-19 strain.

—	U.-19	N. R. cotton
	Per cent.	Per cent.
1923	37·5	35·8
1925	36·4	35·8

(*c*) The yield per plant is less than that of the mixture of strains known as N. R. cotton, as will be seen by the following figures :—

—	U.-19		N. R. cotton	
	1923	1925	1923	1925
Mean yield of seed cotton per plant in grams	39·0	33·3	41·5	35·3

Variation in size of shape of cotton bolls in Khandesh (type U.19, and the prevailing type N. R.).

It was selected for its large sized bolls, as at the time the selection was made this was supposed to be an important character in determining yield. This has proved not to be the case with this strain and it is simply maintained as one type of the variety.

4. *Black Seeded N. R.*

This was a strain of the *rosea* variety isolated at Surat on account of its supposed earliness and grown at Dhulia since 1921.

The leaves of this type are aglandular. In respect of earliness it has not been earlier than others in the matter of opening flowers, but in that of opening the bolls it has been found to be about a week earlier than the average of N. R. cotton. The bolls of this strain are small in size and the amount of seed cotton per boll is low. The other characters as recorded in 1924 and 1925 are as follows :—

Characters of strain black-seeded N. R.

—	Black Seeded N. R.		N. R. cotton	
	1924	1925	1924	1925
Mean yield of seed cotton per boll in grm.	1·9	..	2·4	2·3
Mean yield of seed cotton per plant in grm.	50·1	25·5	45·3	35·3
Ginning percentage	38·5	36·0	34·7	35·8
Staple in mm.	12·0	12·0	12·7	12·1

These figures show no particular constant qualities of value except the earliness of the type ; it is being maintained for this latter quality.

5 and 6. *N. R. (A) and N. R. (C).*

These decidedly undesirable types are described to show how inferior strains are included in the mixture known as N. R. cotton. They only differ in the glands on the leaves, the first possessing three glands, while the second has none. The possession of glands has not been found to have any relationship with the economic characters of the cotton. Both strains have low ginning percentage, the figures for 1925 being as follows :—

	per cent.
N. R. (A)	33·1
N. R. (C)	33·9

They are, of course, of no value and only show how the value of N. R. cotton could be lowered by the increasing prevalence of such strains.

A summary of some of the general characters of the six strains described is as follows :—

Characters of strains of N. R. cotton.

—	Number of monopodia	Number of leaf glands	Character of bolls	Ginning percentage
Pimpalgaon	2 to 5	three	large (38 × 30 mm.)	38 to 40
U.-29	1 to 3	three		38 to 42
U.-19	1 to 3	three	large (38 × 40 mm.)	36 to 38
Black Seeded N. R.	1 to 2	none	Small (30 × 26 mm).	35 to 37
N. R. (A)	1 to 2	three	small (31 × 26 mm.)	31 to 33
N. R. (C)	1 to 2	none	Small (31 × 26 mm.)	32 to 34

Description of types isolated from Gossypium neglectum elsewhere in India and tested in Khandesh. Closely connected with the study of the types of *neglectum* cotton grown in Khandesh is that of several strains isolated elsewhere which have been tested at Dhulia. Four of these may be mentioned.

1 and 2. Big Bolled N. R. and Rosea from Dharwar. These were two types isolated at the Dharwar Agricultural Station and maintained, the former for its large sized boll (supposed to indicate high yielding capacity in the plants) and the other used there as a parent in a very interesting cross made with *Gossypium herbaceum.*[1] On trial at Dhulia in 1921 and 1922 it was found that both these types, having been isolated under the much longer season conditions of Dharwar, were very late in opening their flowers and bolls. This lateness, amounting to at least three weeks, rendered them quite useless in Khandesh. It was found in 1922 that although the picking of the local cottons was completed by the middle of November, yet these types had not by that time even opened their bolls, and the cold weather adversely affected them before the bolls were open.

3. and 4. J. N. 1 and K. 22. These are two strains of *neglectum* cotton isolated at Cawnpore, the former being a selection from Jalaun cotton with a staple of 0·85 to 0·9 inch, a ginning percentage of 36 and a good yield. The latter is one of the hybrids isolated by Leake. The former in its general characters belonged to the *Gossypium neglectum* var. *vera malvensis,* being broad lobed and yellow flowered. The latter (K. 22) belonged to the *Gossypium neglectum* var. *vera* being narrow lobed and yellow flowered.

[1] Kottur, G. L. Studies in inheritance in cotton, I. *Mem. Dept. Agri., India* (*Bot. Ser.,* Vol. XII, No. 3 (1923).

Grown at Dhulia these cottons gave the following results in the year 1923.

Characters of strain J.N. 1 and K. 22.

—	J. N. 1	K. 22	N. R. cotton
Mean yield of seed cotton per plant in grm.	27·4	35·4	41·5
Ginning percentage	37·1	38·1	37·1
Staple in mm.	13·5	14·0	12·7

There was, therefore, nothing outstanding about either of these types for growth in Khandesh, and in addition, K. 22 showed itself very susceptible to wilt. In consequence they seemed to have no possibilities in this region, and their growth was abandoned.

SUMMARY REGARDING LOCAL AND INTRODUCED NEGLECTUM COTTONS.

It thus appeared that so far as the author's tests have gone, none of the *neglectum* cottons introduced from outside have any possibilities in connection with the improvement of Khandesh cotton. Further, the test of local material showed nothing substantially better than the N. R. cotton (a mixture) now being distributed in the area. If better staple was obtained it was always at the cost of the yield or ginning percentage. The results of very careful selection from local cottons or of the introduction of types outside already isolated was disappointing.

The next step was the collection of cotton seed from various parts of Berar, Central India and the Central Provinces and extensive tours for the purpose were made in December 1923. The material obtained has been grown each year since, and while no final statement can be made regarding it (as the isolated types are not constant in character yet) it may be definitely stated that the results are again disappointing. The types of the *rosea* variety (which almost always yields best) have not given more than a ginning percentage of 41 to 42 per cent. The long staple cottons like selections of *Bani* cotton giving a staple of 22 to 23 mm. have not so far bred true, and are in every case low yielding and low ginning. The types belonging to the variety *vera malvensis* (page 8) have been found quite unsuitable owing to low yield. The search for high yielding cotton of high ginning character and better staple than the prevalent cotton (N. R.) in Khandesh and the surrounding cotton areas has therefore failed so far, and the author has reluctantly concentrated attention on a group of supposed hybrids, the material for which was available.

IV. Supposed Hybrid Cottons suitable for Khandesh.

When the author took charge of the work on the improvement of Khandesh cottons in 1921, there were put into his hands seeds supposed to be the progeny of

hybrids made in 1908 between *Gossypium cernuum* (Comilla cotton) and *Gossypium indicum* (*Bani*). These had been maintained at Dhulia from that time, the undesirable types which appeared being annually discarded and the remainder kept. But as no covering of the flowers had been adopted and as no systematic selection of the progeny had been carried on, it is extremely doubtful what are the elements which the material contained as it came into the author's hands. Whatever it was, it was extremely mixed and it was only after several years of work that a number of strains have been isolated from it. Whatever the genetic composition of the material may be, it has given a number of strains which appear to be of considerable value.

On the presumption that the tradition of the origin of these cottons is correct, a few words may be said indicating the characters of the *Gossypium cernuum*, or Comilla cotton, alleged to be one of the parents.

Comilla cotton (*Gossypium cernuum*) is described by Watt[1] as a variety of *Gossypium arboreum*, and he considered it as an extreme form or a special race of the variety *neglecta*. The leaves are more deeply lobed even than the most lobed variety of *Gossypium neglectum*, with or without accessory lobes. The bracteoles are large. The flowers are pale yellow to white and the petals are nearly twice the length of the bracteoles. The bolls are very long, and in shape very elongated, the seeds are large and flattened, the fuzz is abundant and whitish, the lint is short, white, very coarse and woolly, the lint is of little commercial value except to mix with wool.

The only characters which really distinguish this species from *Gossypium neglectum* var. *rosea* are (1) the length of the bracteoles (2) the shape of the bolls. In fact, in the author's opinion, it might well be considered as a *neglectum* cotton. Watt[1] was of a similar opinion and noted as follows :—" The plant cannot possibly be more than a variety if not rather a special race. It is certainly not a species. There is nothing to justify the retention of the name *Gossypium cernuum*, hence my giving it the name *assamica* to denote its original locality of production. The plant is rapidly crossed with other stocks and soon becomes what can best be described as a large form of var. *neglecta* or at most of var. *rosea*."

Natural cross fertilisation between *Bani* and Comilla cotton has been stated to occur (Watt, *loc. cit.*) and the suggestion has been made that the various forms of *neglectum* cottons have originated from these hybrids. An instance of actual crosses being made by Major Trevor Clarke is recorded by Watt.[2] He aimed at improving the quality of the high yielding Garo Hill cotton by crossing it with *Bani* cotton as early as 1865. The seeds produced are said to have been sent to Nagpur and Akola (Berar) for cultivation. No record as to what happened further to these crosses is available.

There was, therefore, no doubt that *Bani* cotton (*Gossypium indicum*) with its good staple, low yield, and small ginning percentage, and Comilla cotton (so-called *Gossypium cernuum*) with its worthless staple, but very high yield and very high

1. Watt. Wild and cultivated cottons of the World, (1907).
2. *Loc. cit.* p. 336.

ginning percentage, will cross, and that out of the cross it may be possible to obtain types suitable for Khandesh with a combination of desirable characters. Crosses were, therefore, made in 1908, careful individual selection from the resulting material was carried on for two or three years (without covering the plant, however) and thereafter, the seed was maintained by mass selection. The resulting mixture (the botanical constitution of which was naturally unknown) was stated in 1918 to be promising, and in 1921 was considered as some of the most promising material to work upon for the improvement of Khandesh cottons. Each of the so-called types then existing was, however, a complex mass of heterozygotes.

In 1921, the three most promising so called types (B XI, BIV, B XX) were taken in hand at Dhulia. None was found to be homogeneous and their variation may be illustrated by the ginning percentage. This varied in B XI from 16 to 43 per cent., in B IV from 21 to 45 per cent., and in B XX from 22 to 43 per cent.

Ginning per centage of supposed lani-comilla hybrids, 1921-22.

Ginning percentage	FREQUENCY OF OCCURRENCE		
	B XI	B IV	B XX
15—17	1	..	..
17—19	..	..	..
19—21	1	1	..
21—23	1	3	1
23—25	1	2	3
25—27	..	1	2
27—29	4	..	3
29—31	2	3	3
31—33	7	3	4
33—35	6	6	10
35—37	10	11	10
37—39	11	10	9
39—41	6	8	6
41—43	3	1	3
Over 43	1	2	..
	54	51	54

METHOD OF WORK. Fifty plants of each of the lots of seeds (B XI, B IV, and B XX) were labelled as suitable for selfing, and all flowers on each of these plants were selfed. In 1922, out of the progeny, fifty plants from the whole lot of seed were selected for further maintenance and careful study, all flowers being again selfed. The seed from each of these was sown in rows. Those rows which showed large heterogeneity or which generally had not the desired characters in a marked degree were rejected. A study of the gametic purity in the progeny of the desirable types was undertaken by noting the various marked and important morphological features, besides the fundamental basis of selection, namely, yield, ginning percentage and staple length.

As a result of these lines of work, ten types which showed promising results were selected in November 1923, and the method described has now been carried on for a period of five years. This has enabled the author to test accurately the performance record of each individual and to isolate some very desirable strains, which are now constant within the limits of variation of the type. Before describing these strains, it will be worth while to indicate shortly the special characters which are desired in a cotton for the Khandesh tract.

THE IDEAL TYPE OF COTTON FOR KHANDESH. In this area the first and foremost consideration in determining the suitability of a type of cotton is the *yield*. The failure in this respect ruined the attempts to introduce American (New Orleans) cotton and *Bani* cotton, (*vide supra*). The success of N. R. cotton has been primarily due to its high yield, and this is the main reason why it is so popular. The factor or factors which most largely contribute to this outstanding yield in the N. R. cotton will be considered elsewhere. Briefly stated, it would seem that the greater yield is chiefly due to a smaller amount of shedding of bolls, especially of those formed early in the season.

If the cotton gives an adequate yield, the matter of next importance is the ginning percentge. In the present day markets of Khandesh any cotton ginning less than 36 per cent of cotton is not appreciated.

The third factor of importance is that of earliness. In Khandesh a plant, to be really suitable, must complete its life before the cold weather is fully established. Cotton commences to reach the market by the middle of October, and any delay in the first crop means usually a lowering of price.

A fourth factor is the necessity of a cotton being able to resist long droughts. General drought is not uncommon, and in almost every year there are long breaks in the rains which affect some cottons more than others. The actual rainfall in each month of the growing season is shown in the following Table for nine years.

Months.

—	June	July	August	September
	Inches	Inches	Inches	Inches
1918	3·2	2·2	2·0	1·0
1919	9·7	5·3	4·7	8·7
1920	1·8	5·9	2·1	2·3
1921	3·2	9·9	3·6	8·8
1922	8·3	4·1	0·6	3·8
1923	0·2	11·3	1·2	10·1
1924	2·2	3·4	8·4	7·5
1925	7·4	1·7	3·3	2·9
1926	1·95	8·81	6·23	1·85

The rainfall conditions are still better shown in Fig. 4 which shows the actual amount of rain received from day to day during the season.

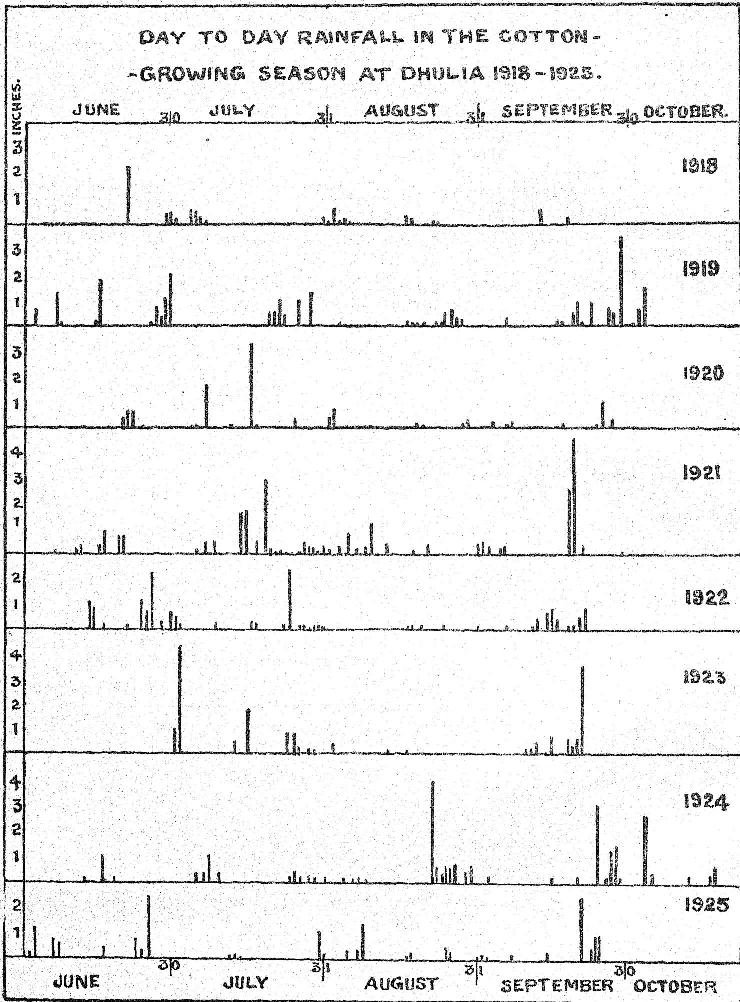

DAY TO DAY RAINFALL IN THE COTTON-
-GROWING SEASON AT DHULIA 1918-1925.
INCHES.
JUNE
30
JULY
31
AUGUST
31
SEPTEMBER
30
OCTOBER.
1918
1919
1920
1921
1922
1923
1924
1925
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER

FIG. 4.

A fifth factor of importance is the necessity of a sympodial habit of growth, leading to an erect plant. This is probably an essential for an early plant. At any rate, all monopodial types, such as those cultivated in Gujarat, have a very small percentage of success in the bolls formed in the plant. The percentage of bolls ripening on the plants of different strains in 1924 at Dhulia compared with the number of flowers formed on sympodia and monopodia respectively is shown in the following Table.

Percentage of flowers formed yielding ripe bolls.

—	Primary on sympodia	On monopodia
	Per cent.	Per cent.
B XI. 9 (34)	43·9	2·1
B IV. 50	49·3	0·0
B XX. I	53·4	1·8
B XX. 27	43·7	3·1
B XI. 54	48·1	3·3
N. R. cotton	45·6	7·3

When these necessitates in a cotton suitable for Khandesh have been provided for, and only then, can the question of staple be considered. So that the aim must be to get the best possible staple consistent with retaining an early sympodial cotton, capable of resisting a considerable amount of drought, with a high yield comparable with that of N. R. cotton and giving a ginning percentage of over 36.

SELECTIONS FROM SUPPOSED HYBRID COTTONS. The ideal type of cotton having been described, it will be seen that none of the selections from indigenous or introduced cottons of the *neglectum* series have approached the mixture of strains of the *rosea* variety, known as N. R. cotton. It remains to be seen how far these requirements can be met from the supposed hybrids between *Gossypium cernuum* (Comilla) and *Gossypium indicum* (*Bani*) whose origin has already been described. As a result of five years of selection work on these cottons, several types, breeding true, may now be described.

Dhulia No. I (Plates I and IV).

This is the name given by the author to a selection breeding true, from the seed known as B XX, and said to be derived from a cross between the species named, made in 1908.

In appearance this gives a plant generally similar to the type of the *rosea* variety of *Gossypium neglectum.* It has proved itself as hardy as N. R. cotton, and resists equally well the drought conditions and the vagaries of rainfall as the latter. It is a quick and vigorous grower, and in its early stages can be distinguished from the ordinary plants of the *rosea* variety by the fact that in this strain the leaves have *no accessory lobes at all.* The other character by which it can be distinguished is the colour of the flower, which is pale yellow (or sulphur white). The special features which characterise the type are as follows:—

Earliness. Perhaps the most striking feature of this strain is its earliness. As stated previously, the mixture known as N. R. cotton is much the earliest of the types of *neglectum* cotton: this type is as early as N. R. cotton. In fact, judged by the number of flowers formed week by week during the season and their percentage of success, there is practically no difference between the two.

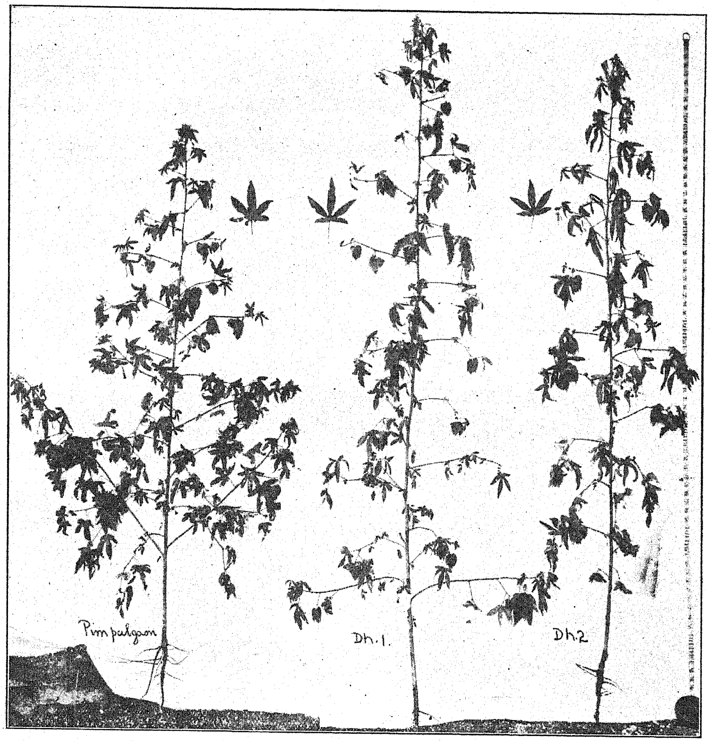
Yield. Yield comparisons with N. R. cotton were made (*a*) in pedigree culture rows of about 100 plants in 1923, 1924 and 1925, (*b*) in plots of one sixteenth of an acre at Dhulia in 1924, (*c*) in two-row tests replicated four times at Dhulia in 1925, (*d*) in plots of one quarter of an acre at Jalgaon in 1925, and (*e*) in plots of two acres each at Jalgaon in 1925. The results are as follows. All yields are of *seed cotton.*

(*a*) *Pedigree culture rows.*

Year	Strain	Number of plants	Mean yield per plant
			grams
1923	Dhulia No. I	97	$40·4\pm1·10$
	N. R.	93	$41·5\pm1·18$
1924	Dhulia No. I	82	$44·7\pm0·01$
	N. R.	85	$45·3\pm1·13$
1925	Dhulia No. I	101	$29·6\pm0·49$
	N. R.	123	$35·3\pm0·70$

(*b*) *Plot of one-sixteenth acre at Dhulia 1924.*

Strain	Yield per plot	Yield per acre
	lb.	lb.
Dhulia No. I	37	592
N. R.	30½	488



Plant habit of certain types of cotton in Khandesh (Dhulia No. 1, Dhulia No. 2 and Pimpalgaon).

(c) Replicated two-row plots at Dhulia (1925).

Strain	Yield per plot					
	1	2	3	4	5	Mean
	lb.	lb.	lb.	lb.	lb.	lb.
Dhulia No. I	3·2	4·4	4·2	4·3	4·5	4·1
N. R.	4·2	3·5	4·7	6·0	6·1	4·9

(d) Replicated plots of one quarter acre at Jalgaon (1921).

Strain	Yield per plot			Yield per acre	
	1	2	3	4	5
	lb.	lb.	lb.	lb.	lb.
Dhulia No I	138	148	124	122	532
N. R	178	114	144	128	564

(e) Two acre-plots at Jalgaon (1925).

Strain	Yield per plot (2 acres)	Yield per acre
	lb.	lb.
Dhulia No I	1,502	751
N. R.	1,366	683

These results show that we have in the type Dhulia No. I a strain yielding nearly as much as the standard N. R. cotton.

Ginning percentage. Grown in pedigree culture rows in three successive years the following figures were obtained.

Year	Number of plants	Mean ginning percentage
1923	97	36·5±0·09
1924	82	37·7±0·09
1925	122	36.±0·08

When grown on bigger areas the following results in ginning percentage were obtained, as compared with N. R. cotton, both at Jalgaon and Dhulia.

Place of experiment	Area	Ginning Percentage	
		Dhulia No. I	N. R. cotton
Jalgaon	¼ acre (Average of four plots). . . .	36·8	34·7
Jalgaon	Two acres	38·2	32·5
Jalgaon	Five acres	39·2	33·8
Dhulia	Replicate two-row plots	36·8	35·7

The results show a cotton which gives distinctly higher ginning outturn than the standard previously laid down (36 per cent) and rather better than N. R. cotton.

Staple. The characters so far considered place this strain at least on a par with N. R. cotton. Its value will, therefore, be determined by its staple, and here it is distinctly better than N. R. cotton. Thus in 1924 its staple varied from 13·8 to 16·8 mm. only, with the mode at 15·8 mm. Grown under similar conditions, N. R. cotton gave a much wider variation in staple, from 9·8 to 16·3 mm. with several modes, the highest being at 11·8 mm. The variation in the staple as compared with N. R. cotton is shown in Fig. 5.

When submitted to commercial examination, the following report was obtained.

Cotton	Value	Remarks
	Rs.	
Dhulia No. I	371 per candy	Barely superfine, C. P. 2. Staple fair, about Rs. 7 on 'Fine C. P. 2.'
N. R. Cotton	335—340 per candy	Barely fair staple. It is better than extra Super fine Bengal types, but staple is inferior to Oomra.

The report of the Technological Laboratory, Bombay, on this cotton is given in the Appendix. It shows that while N. R. cotton will barely spin 10's, this type will almost spin 20's.

General. We have thus a cotton which, though equal or nearly equal to the standard N. R. cotton in yield and ginning percentage, shows considerable superiority in point of staple and fineness. It is, moreover, a quick and vigorous grower, and bears leaves which are without an accessory lobe, and so enable it to be easily indentified even in an early stage of growth. It is now being multiplied on a large scale.

Dhulia No. 2 (Plates I and IV).

This is the name given by the author to a selection breeding true from the seed known as B XI, and said to be derived from a cross, between the species named, made in 1908.

This strain, like Dhulia No. I, has deeply lobed leaves, the lobes of which likewise bear no accessory lobes. The lobes are, however, slightly broader than Dhulia No. 1 and are much darker in colour. During the growing period, it can very easily be distinguished by this dark colour and by the drooping nature of the leaves. The stipules that it bears are quite prominent in contrast to those of Dhulia No. 1, in which they are long and slender, and hence, inconspicuous.

This type is almost exclusively sympodial. It has practically no limbs, and far less than either Dhulia No. I or N. R. cotton. The percentage of plants with various numbers of monopodia in 1925 at Dhulia is as follows :—

Number of monopodia	Percentage with each number of monopodia		
	N. R. cotton	Dhulia No. 1	Dhulia No. 2
	Per cent.	Per cent.	Per cent.
0	6	11	87
1	19	27	7
2	29	38	5
3	27	16	1
4	17	5	..
5	2	2	..
6	..	..	..
7	..	..	..
8	..	1	..

Yield. Yield comparisons with N. R. cotton were made in pedigree culture rows of about 100 plants in 1924 and 1925, and in two-row replicated plots at Dhulia in 1925. The results are as follows :—

(*a*) *Pedigree culture rows* (*1924 and 1925*).

Strain	Mean yield per plant	
	1924	1925
	grams	grams
Dhulia No. 2	44·2±1·37	27·9±0·60
N. R.	45·3±1·13	35·3±0·70

(b) Replicated two-row plots at Dhulia (1925).

Strain	Yield per plot					
	1	2	3	4	5	Mean
	lb.	lb.	lb.	lb.	lb.	lb.
Dhulia No. 2	3·7	2·9	4·3	3·9	3·6	3·7
N. R.	2·9	2·5	4·9	5·0	3·7	3·8

The results are not very definite, but they indicate a lower yield than in the standard N. R. cotton.

Ginning percentage. Grown in pedigree culture rows in two successive years, the following figures were obtained :—

Year	Mean ginning percentage
1924	37·9±0·18
1925	35·8±0·13

From the type grown over a quarter of an acre, the ginning percentage was 36·1.

These results show a cotton, which is satisfactory from the point of view of ginning percentage.

Staple. In point of staple, this strain is one of the best selections made. Thus in 1924, its staple varied from 17·8 to 21·2 mm. with the mode from 18·8 to 19·8 mm. Grown under similar conditions, N.R. cotton gave a much wider variation in staple, from 9·8 to 16·3 mm. with several modes, the highest being at 11·8 mm. It is thus in an entirely different class, in respect to staple, from N. R. cotton. The variation in staple as compared with N. R. cotton is shown in Fig. 5.

When submitted to commercial examination, the following report was obtained.

Cotton	Value	Remarks
Dhulia No. 2	Rs. 384 per candy	Good colour, Staple fair to good, but irregular, Class fine to superfine C. P. I., with value Rs. 5 on for staple, and Rs. 5 on for class on 'Fine C. P. No. I.'
N. R. cotton	335—340 per candy	Barely fair staple. It is better than extra superfine Bengal types, but staple is inferior to Oomra.

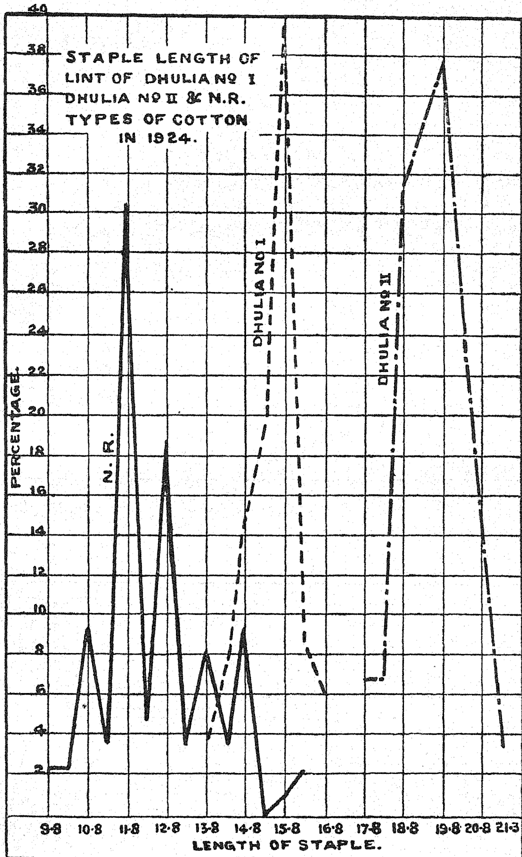

STAPLE LENGTH OF LINT OF DHULIA Nº I DHULIA Nº II & N.R. TYPES OF COTTON IN 1924.
PERCENTAGE.
LENGTH OF STAPLE.
N. R.
DHULIA Nº I
DHULIA Nº II
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
9·8
10·8
11·8
12·8
13·8
14·8
15·8
16·8
17·8
18·8
19·8
20·8
21·3

FIG. 5.

The report of the Technological Laboratory, Bombay, on this cotton is given in the Appendix. It shows that while N. R. cotton will barely spin 10's, this type will under favourable circumstances spin 30's to 32's.

General. We have here a cotton which has a ginning percentage of over 36, and a staple distinctly higher than any type of *neglectum* cotton in cultivation in Khandesh. In point of yield, its position is not quite certain as yet.

Other cotton types.

The two strains just described as Dhulia No. 1 and 2 are the strains which meet most closely the conception of an ideal cotton type for Khandesh, but it is of interest to describe shortly other strains which have been isolated from the mixed material placed before the author in 1921. These represent the best which was found in this mixed material and each of them has been maintained for one or other reason.

B. IV 50. This has been evolved from the original mixture known as B. IV. Its sympodial habit is specially characteristic (Plate V). The actual proportion of plants containing various numbers of monopodia in the three years 1923, 1924 and 1925 was as follows :—

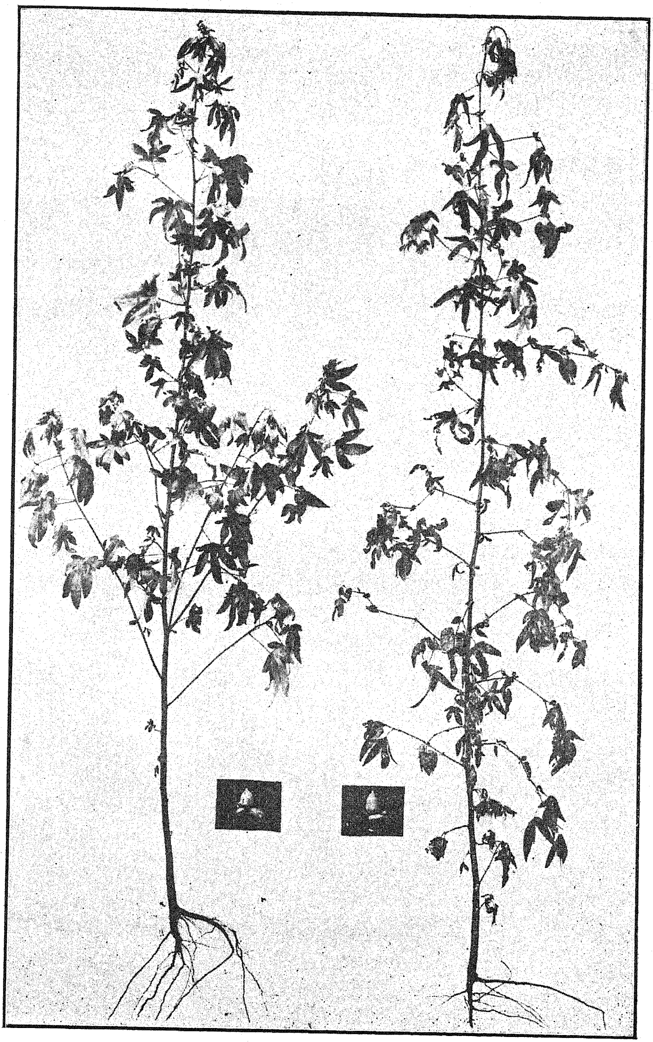
Monopodia in strain No. B IV. 50.

Year	Number of plants taken	Plants with various number of monopodia				
		0	1	2	3	4
1923 . . .	99	62	33	4	..	..
1924 . . .	72	29	11	16	13	3
1925 . . .	107	102	4	1	..	..

Owing to the absence of monopodia, the first primary fruiting branch has been found to arise at a much lower node than in other types. The following Table compares it, in this particular, with N. R. cotton.

Node of origin of first sympodium.

Year and strain	Number of plants	Number with first sympodium at various nodes								
		6th node	7th node	8th node	9th node	10th node	11th node	12th node	13th node	14th node
1923										
B. IV. 50 .	99	13	*48*	25	12	1	..	..	..	..
N. R. . .	98	..	3	4	32	*35*	15	6	3	..
1924										
B. IV. 50 . .	104	2	20	*43*	34	5	..	..	..	..
N. R. . .	103	..	2	1	12	27	*33*	19	7	2
1925										
B. IV. 50 . .	125	4	*61*	43	14	3	..	..	..	..
N. R. . .	125	..	1	2	17	26	*34*	32	8	5



Plant habit of certain types of cotton in Khandesh (B. IV. 50 and Pimpalgaon).

The production of these fruiting branches at a lower node is generally connected with the early appearance of flowers. As stated previously the formation of a large number of flowers in the early part of the growing period is an object to be aimed at, as this usually means a large proportion of bolls to flowers. The amount of shedding (page 43) with this strain is high, however, and thus the yield is low in spite of the early flowering.

The other prominent features of this strain are as follows. The stem is weak, and hence the plants are liable to lodge. It has another, even worse, defect, in that it is extremely susceptible to wilt.

Its stipules are very large and conspicuous. The bracteoles are also large and cover up the boll entirely.

Its yield is shown in the following tests, as compared with N. R. cotton.

(*a*) *Pedigree culture rows* (*1923, 1924 and 1925*).

Strain	Mean yield per plant		
	1923	1924	1925
	grams	grams	grams
B. IV. 50	36·9 ± 0·79	43·9 ± 1·18	25·2 ± 0·61
N. R.	41·5 ± 1·18	45·3 ± 1·13	35·3 ± 0·70

(*b*) *Replicated two-row plots at Dhulia* (*1925*).

Strain	Yield per plot					Mean
	1	2	3	4	5	
	lb.	lb.	lb.	lb.	lb.	lb.
B. IV. 50	3·3	3·8	2·6	3·3	4·6	3·5
N. R.	3·6	4·5	4·7	5·1	4·4	4·5

(*c*) *Replicated plots of one quarter acre at Jalgaon* (*1925*).

Strain	Yield per plot				Yield per acre
	1	2	3	4	
	lb.	lb.	lb.	lb.	lb.
B. IV. 50	130	102	110	94	436
N. R.	178	114	144	128	564

(d) Two acre plots at Jalgaon (1925).

Strain	Yield per plot (2 acres)	Yield per acre
	lb.	lb.
B. IV. 50	1110	555
N. R.	1366	683

All these tests indicate a lower yield than N. R. cotton.

The ginning percentage in pedigree culture has been

1923	$35{\cdot}7 \pm 0{\cdot}07$
1924	$36{\cdot}8 \pm 0{\cdot}12$
1925	$35{\cdot}5 \pm 0{\cdot}05$

On bigger plots its ginning percentage was in 1925.

	Per cent
(1) at Jalgaon	36·7 and 36·3
(2) at Dhulia	37·2

Its ginning outturn is, therefore, good, and equal to the two selections previously described.

In staple it is equal to Dhulia No. 2 and it is capable of spinning up to 30's. The report of the Technological Laboratory is found in the Appendix, and the grader's report is as follows :—

B. IV. 50 Value Rs. 404 per candy, as against Rs. 335—340 for N. R.

Good colour and nice staple. Rs. 10 *on* 'Superfine C. P. I.'

Its failure in point of yield is disappointing, as in other results it stands out among all the selections made.

B. XX. I (Plate VI). This was a selection made from B. XX. Morphologically it does not differ from the Dhulia No. I which it closely resembles in all respects except in staple. So far its yield has been low, with a ginning percentage of about 35. The object for which it has been maintained is its staple, and particulars with regard to its spinning value will be found in the Appendix. The grader's report was as follows :—

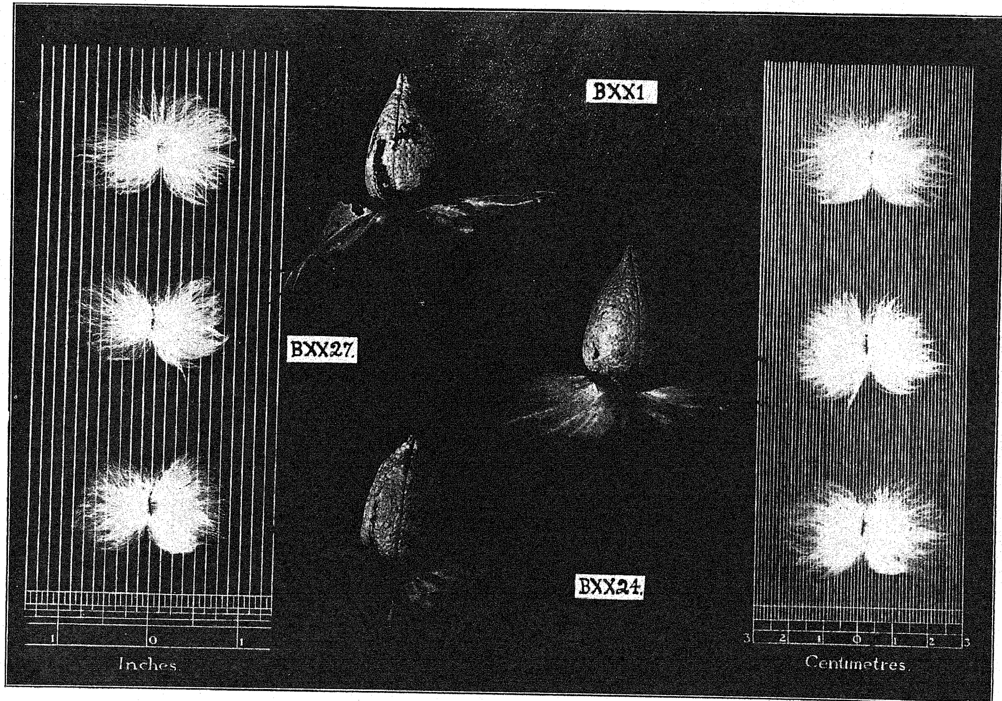
B. XX. I value Rs. 430 per candy as against Rs. 335—340 for N. R.

Better than B. IV. 50 in style and staple. Value is about superfine Punjab-American, or Rs. 26 per candy on 'superfine C. P. I.'

This again fails in point of yield, and its ginning percentage is hardly up to the standard.

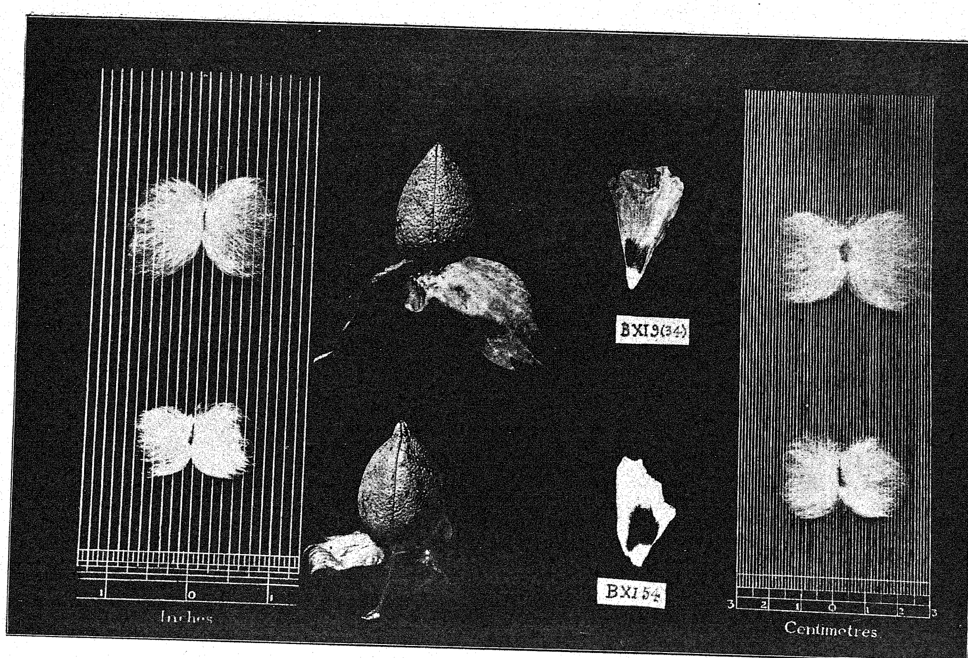
B. XI. 9 (3). This is a selection originally made from the same material as Dhulia No. 2. It is very similar to the latter in respect of leaf, bolls and flowers. The two types, while growing, can in fact only be distinguished

PLATE VI.

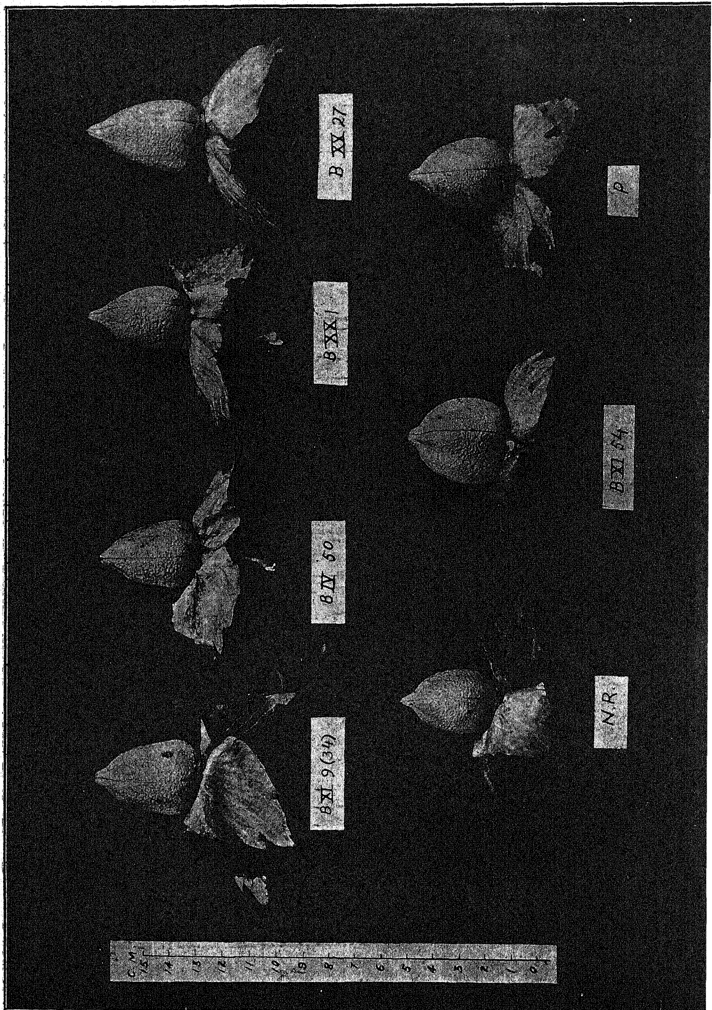


Boll and staple characters of improved types of cotton for Khandesh (B. XX. 1, B. XX. 27, Dhulia No. 1 & B. XX. 24).

PLATE VII.



Boll, staple and other characters of improved types of cotton for Khandesh (B. XI. 9 (34)=Dhulia No. 2 & B. XI. 54).


B XX 27
B XX 1
B IV 50
B XI 9 (34)
P
B XI 54
N.R.
C.M.

by the stipules, which are small and inconspicuous. Its main characters in two years are as follows :—

—	Yield per plant	Mean ginning percentage	Mean staple
1924	grams	Per cent.	mm.
B. XI. 9(3)	37·3	34·1	20·9
N. R.	45·3	34·7	12·7
1925			
B. XI. 9(3)	24·3	32·7	20·5
N. R.	35·3	35·8	12·1

B. XI. 54 (Plate VII). This type, though isolated from the same lot of material as has provided Dhulia No. 2 differs from the latter and the other strains isolated both in habit of growth, and in the colour of the flowers. It bears a stout stem and fruiting branches, and is a very vigorous grower. If the September and October rains continue, a number of axilliary shoots arise in the axils of the sympodial branches, and produce short new fruiting branches, thus increasing its productive capacity. Although, however, it bears many flowers, its shedding index is high (page 43).

This strain has leaves with accessory lobes, and it bears white flowers. It is, therefore, indistinguishable from the ordinary *rosea* variety of *neglectum* cottons. Its ginning percentage is very high as follows :—

	Mean ginning percentage
	Per cent.
1923	40·5
1924	42·3
1925	39·4

The bolls are large in size, and oval in shape (Plate VII).

The quantity of seed cotton per boll is high, and this might lead us to expect a large yield per plant and per acre. The actual yield results as are follows :—

(*a*) *Pedigree culture rows* (*1923, 1924 and 1925*).

Strain	Mean yield per plant		
	1923	1924	1925
	grams	grams	grams
B. XI. 54	43·8±2·25	53·9±1·39	29·2±0·51
N. R.	41·5±1·18	45·3±1·12	35·3±0·70

(*b*) *Replicated two row plots at Dhulia* (*19*:*5*).

Strain	Yield per plant					Mean
	1	2	3	4	5	
	lb.	lb.	lb.	lb.	lb.	lb.
B. XI. 54	4·3	4·0	3·3	3·6	3·8	3·8
N. R.	7·9	6·5	4·6	4·1	4·5	5·5

In the year 1924, a very good year the yield was the highest among the selections; it has lost its position in 1925 when it appeared decidedly inferior to N. R. cotton in yield. This year was a very poor one for yield generally, but the strain now being discussed seemed to suffer worse than others. In unfavourable years, it has shown itself to be specially liable to the attack of both spotted boll worm (*Earias sp.*) and the pink boll worm (*Gelechia gossypiella*). Its liability to shedding appears, however, to be the factor which chiefly limits its yielding power.

In staple length it is slightly superior to N. R. cotton, giving a measurement of 15mm. as against 12mm. for the latter. It has, however, been valued by the Technological Laboratory, Bombay and the following remark was made in the report. " This strain suffers from giving rather more waste (about 1·5 per cent. more) which lowers its grade and detracts from its value, although in the spinning test it is decidedly superior in its performance to N. R. cotton." The graders make it slightly *less* valuable than N. R. cotton.

B. IV. 45. This selection resembles the last in respect of lobing, but can be distinguished from it by the characters of the flowers. The petals, though white, are enclosed within the bracts and do not emerge beyond them as in B. XI. 54. In this respect, it is not distinguishable from the mass ot the *rosea* variety of *neglectum* cotton in cultivation.

Its chief merit consists in its high ginning percentage as seen from the following figures.

	Ginning percentage
	Per cent.
1923	42·1
1924	44·7
1925	41·1

In staple it is no better than N. R. cotton, though in feel it is silky, the yield results are not encouraging. It has been maintained for its exceptionally high ginning percentage, which may give it a special use for future crossing.

It may be interesting to note that, in all the selections made, in no case has a good staple been associated with a white flower. Whether this is anything more than a

coincidence can hardly be determined at present. But attention may be called to the fact that the white flowered strain in the *Wagad* variety of *Gossypium herbaceum* (otherwise exclusively a yellow flowered cotton) is stated by Patel and Mankad[1] as having a staple distinctly shorter than the other strains of this cotton.

V. Factors influencing Yield in Khandesh Cotton.

The principal merit of Khandesh cotton as now grown, and especially of the N. R. type of it, is the high yield which it gives and any improved cotton offered to the growers must have, as already described, a similar or only slightly inferior yield. Yield, however, depends on a number of factors. The present study has only considered some of these, but the observations so far made are of considerable interest. The author has taken into consideration the following ways in which high yield could be obtained.

(1) an innately high productive capacity of the plants in number of flowers.
(2) a low shedding index.
(3) a period of intensive flowering during a short portion of the season when conditions are most favourable for boll formation and ripening.
(4) a large number of fruiting branches.
(5) a large number of buds per fruiting branches.
(6) a large amount of seed cotton per boll.

This study was undertaken in the first instance with the idea of isolating a type which had an intensive flowering period within a very short part of the season when the chance of the successful formation of bolls from flowers was at its highest. In the year 1924, observations were in fact limited to the number of flowers opened each day, so as to determine the percentage of success in bolls. The scope of the enquiry was, however, enlarged in 1925 and an attempt was made to estimate the proportion of shedding in the form of buds as well as in the form of bolls and also, incidentally to determine the proportion of shedding due to insects.

PLAN OF WORK. In 1924, eleven strains were selected for purposes of study and twenty five plants were labelled in each. The flowering record was kept daily. Flowers formed on primary fruiting branches (sympodia) and on monopodia were separately noted. The flowers as they opened were ticketted and each ticket showed the date of opening of the flower, and that on which the boll burst. The results in 1924 are not so reliable as in 1925, as in the former year some of the flowers with their tickets were swept off in a heavy storm in September. In 1925 no such incident occurred. In 1925 only six strains were under observation as it was thought wise to make more elaborate notes on each, showing the shedding in different forms (buds, flowers and bolls) and the part played by insects.

[1] Patel and Mankad. Studies in Gujarat Cotton, III. *Mem. Dept. Agri. India, Bot. ser.*, Vol. XIV, No. 2 (1926).

PRODUCTIVE CAPACITY. Since yield very largely depends on the innate productive capacity of the plants, the total bearing capacity of the different strains under similar conditions was determined by noting the buds formed which ultimately developed into flowers. The figures found were as follows taken from sixteen plants in 1924, and from twenty one plants in 1925.

Strain	Number of buds which produced flowers	
	1924	1925
Dhulia No 1	90	90
Dhulia No. 2	66	82
B IV. 50	80	85
B XX. I	67	76
N R. cotton	82	99
B XI. 54	107	89
B XX. 24.	78	..
B IV. 45	94	..
Pimpalgaon	79	..
Black seeded N. R.	99	..
N. V. 66	102	..

The relative order of the strains in the two years is different and this, it may be assumed, is connected with the differing character of the season in respect to rainfall (pp. 25-26). In 1924 there was a heavy downpour of rain on September 24, amounting to 3·22 inches. This caused the strain B. XI. 54, a very vigourously growing type, to put on a fresh green appearance, and hence encouraged the formation of new flower buds. Dhulia No. I which showed a higher productive capacity than N. R. cotton in 1924, a season which encouraged vigourous growth, fell below it in 1925 when only the hardiest types did well.

FLOWERING AND BOLLING. The actual yield obtained depends, as already noticed, not only on the productive capacity, but on the number of buds and flowers which survive the various chances of shedding. The following Table shows the percentage of opened flowers which succeded in producing ripened bolls in the various strains in 1924 and in 1925, and the percentage in each week through the season.

Statement showing the efficiency of boll production for the years 1924 and 1925.

(The number of plants in 1924 was 16 and that in 1925 was 21.)

Type	1st week: No. of flowers formed	1st week: No. of bolls successful	1st week: % of success	2nd week: No. of flowers formed	2nd week: No. of bolls successful	2nd week: % of success
Dhulia 2, 1924	69	24	*34·78*	85	57	*67·05*
Dhulia 2, 1925	54	36	*66·6*	90	71	*78·8*
Dhulia 1, 1924	79	36	*45·56*	97	69	*71·13*
Dhulia 1, 1925	16	12	*75·0*	57	44	*77·1*
N. R., 1924	70	42	*60·0*	101	66	*65·0*
,, 1925	25	19	*76·0*	64	45	*70·3*
B. IV. 50, 1924	84	40	*47·61*	71	46	*64·78*
,, 1925	60	23	*38·3*	73	20	*27·3*
B. XX. 1, 1924	62	26	*41·93*	68	56	*82·35*
,, 1925	15	5	*33·3*	51	35	*68·6*
B. XI. 54, 1924	135	3[illegible]	*26·66*	64	53	*82·93*
,, 1925	54·8	28	*51·0*	92·1	46·6	*50·5*
Black seeded N. R., 1924	38	21	*55·26*	106	73	*68·86*

Type	3rd week: No. of flowers formed	3rd week: No. of bolls successful	3rd week: % of success	4th week: No. of flowers formed	4th week: No. of bolls successful	4th week: % of success
Dhulia 2, 1924	112	81	*72·32*	173	77	*44·5*
Dhulia 2, 1925	108	57	*52·7*	137	76	*55·47*
Dhulia 1, 1924	131	97	*74·04*	189	109	*57·67*
Dhulia 1, 1925	92	71	*77·1*	120	73	*60·8*
N. R., 1924	109	87	*79·81*	167	104	*62·27*
,, 1925	113	84	*74·3*	183	132	*72·1*
B. IV. 50, 1924	128	85	*66·40*	181	111	*61·32*
,, 1925	66	41	*62·1*	89	63	*70·7*
B. XX. 1, 1924	93	70	*75·26*	138	91	*65·94*
,, 1925	76	59	*77·6*	105	67	*63·8*
B. XI. 54, 1924	86	49	*56·97*	118	76	*64·4*
,, 1925	123·6	65·3	*52·4*	126	75·8	*60·15*
Black seeded N. R., 1924	120	88	*73·33*	206	147	*71·35*

Type	5th week: No. of flowers formed	5th week: No. of bolls successful	5th week: % of success	6th week: No. of flowers formed	6th week: No. of bolls successful	6th week: % of success
Dhulia 2, 1924	132	31	*23·48*	92	40	*43·47*
Dhulia 2, 1925	144	73	*50·69*	161	37	*22·98*
Dhulia 1, 1924	508	168	*33·05*	71	39	*54·9*
Dhulia 1, 1925	164	86	*52·4*	168	79	*47·0*
N. R., 1924	160	39	*24·37*	75	44	*58·66*
,, 1925	231	141	*61·0*	258	78	*30·2*
B. IV. 50, 1924	156	51	*32·69*	73	34	*46·59*
,, 1925	120	58	*48·3*	133	68	*51·1*
B. XX. 1, 1924	128	50	*39·06*	59	29	*49·15*
,, 1925	140	81	*57·8*	160	62	*38·7*
B. XI. 54, 1924	168	86	*51·19*	87	61	*70·11*
,, 1925	151·6	82·8	*54·6*	197·1	61·8	*31·3*
Black seeded N. R., 1924	225	116	*51·55*	93	47	*50·53*

Statement showing the efficiency of boll production for the years 1924 and 1925.

(The number of plants in 1924 was 16 and that in 1925 was 21)

Type	7th week			8th week			9th week			10t hweek			11th week			Total of the season		
	No. of flowers formed	No. of bolls successful	% of success	No. of flowers formed	No. of bolls successful	% of success	No. of flowers formed	No. of bolls successful	% of success	No. of flowers formed	No. of bolls successful	% of success	No. of flowers formed	No of bolls successful	% of success	No. of flowers formed	No. of bolls successful	% of success
Dhulia 2, 1924	31	7	22·58	..	..	..	..	..	..	..	..	..	..	..	..	694	317	45·67
„ 1925	108	18	17·3	43	4	9·52	21	..	0	12	..	0	5	..	..	883	373	42·24
Dhulia 1, 1924	54	8	14·81	..	..	..	..	..	..	..	..	..	..	..	..	1129	526	46·58
„ 1925	120	28	23·3	65	16	24·6	11	2	18·1	6	3	50·0	..	..	..	819	414	50·54
N. R., 1924	67	5	7·49	..	..	..	..	..	..	..	..	..	..	..	..	749	387	51·66
„ 1025	226	25	11·0	71	13	18·3	11	1	9·0	16	4	25·0	2	..	0	1200	542	45·16
B. IV. 50, 1924	68	9	13·23	..	..	..	..	..	..	..	..	..	..	..	..	761	376	49·4
„ 1925	139	45	32·3	67	19	28·3	30	12	40·0	8	1	12·5	1	...	0	786	350	44·52
B. XX. 1, 1924	47	5	10·63	..	..	..	..	..	..	..	..	..	..	..	..	595	327	54·95
„ 1925	141	21	14·8	38	10	26·3	17	3	17·6	3	3	100	1	..	0	747	346	46·31
B. XI. 54, 1924	32	5	15·62	..	..	..	..	..	..	..	..	..	..	..	..	690	366	53·04
„ 1925	135·3	11·6	8·57	43·1	8·1	18·7	3·5	3·5	100	..	..	..	..	..	..	927·4	383·8	41·38
Black seeded N. R., 1924	31	2	6·45	..	..	..	..	..	..	..	..	..	..	..	..	819	494	60·31

One thing seems clear from these figures. The earlier formed flower buds are generally more effective in producing bolls than the later ones, and the time of great efficiency is in the third and fourth week from the time the first flowers appear. This applies to all strains.

SHEDDING. The next important factor influencing yield is the shedding. In this both the shedding of buds and of bolls is involved. In 1924 the total amount of shedding was determined. In 1925, the shedding of buds and bolls was separately ascertained. The following Tables show the percentage of shedding in the cottons under study in the two years for the strains under study. The number of plants under observation in 1924 was sixteen and in 1925 was twenty-one.

Strain 1924	Percentage of shedding in buds and bolls
	Per cent.
Dhulia No 1	79·2
Dhulia No. 2	71·9
B IV. 50	66·7
B XX. I	66·8
N. R. cotton	67·6
B XI. 54	76·9
B XX. 24	73·1
B IV. 45	71·2
Pimpalgaon	72·5
Black seeded N. R.	65·0
N. V. 66	75·4

These observations in 1924 suffered from two errors. As the observations in the buds and bolls shed were taken once a week, some of the buds that had withered and had left no scars or only very minute ones escaped notice. Further, the new buds formed very close to the old ones or at the end of the fruiting branches could not be counted with accurracy after shedding. In 1925 more frequent counts were made.

Strain	1925 Percentage of shedding		
	Buds	Bolls	Total
Dhulia No. 1	56·7	21·4	78·1
Dhulia No. 2	48·9	29·8	78·7
B IV. 50	55·9	24·4	80·3
B XX. 1.	53·4	25·0	78·4
N R. cotton	42·6	31·5	74·1
B XI. 54	50·4	29·0	79·4

From these figures it is clear that one of the very outstanding features of N. R. cotton is the small proportionate loss of buds formed. This observation is limited to one year only, but is so marked that, in spite of a larger loss of bolls, the total loss is reduced from 78 to 74 in this case.

WEIGHT OF SEED COTTON PER BOLL AND NUMBER OF FRUITING BRANCHES.

The other factors which may contribute to the determination of the yield of a strain are (1) the weight of seed cotton per boll (2) the number of fruiting branches and (3) the number of buds per fruiting branch. The results of two years' observation (1924 and 1925) on sixteen and twenty one plants respectively are as follows :—

Strain	Mean number of sympodia per plant		Mean number of bud per fruiting branch		Mean weight of seed cotton per boll	
	1924	1925	1924	1925	1924	1925
					grm.	grm.
Dhulia No. 1	24	24·5	3·7	3·6	2·44	2·34
Dhulia No. 2	27	25·6	2·4	3·2	2·43	2·34
B IV. 50	25	27·4	2·8	3·1	2·38	3·32
B XX. I	22	23	3·0	3·3	2·21	2·17
N R. cotton	25	23·6	3·2	4·2	2·43	2·37
B XI. 54	29	27·9	3·7	3·1	3·11	2·69

In these figures the very large number of buds per fruiting branch of N. R. cotton in the poor season of 1925 may be noted. In the strain B XI. 54 the large number of primary fruiting branches (sympodia) and the large weight of seed cotton per boll is very noticeable. In the latter case, these high figures have not, however, been able to neutralise the high percentage of shedding with this strain.

TENTATIVE CONCLUSIONS. It seems fair, as a result of this study up to date, to put forward the following tentative conclusions as regards the factors determining yield in a sympodial, rapidly ripening, cotton like that grown in Khandesh.

1. The period of intensive flowering, namely that from the 5th to 7th week from the commencement of flowering, is in close relationship with an intensive period of shedding of bolls.

2. The percentage of total shedding including buds and bolls ranges from 65 to 80 in the cottons so far studied. The proportion shed in the form of buds is by far the greatest.

3. The early formed flowers, more especially those that were formed in the third or fourth week of flowering, are more effective in boll production than those flowering later.

4. No striking difference was noticed in the weight of seed cotton per boll, except in the case of the strain B XI. 54, and in this case it was not able to give high yield on account of high shedding. The number of buds per frui ing branch was not widely different, except with N. R. cotton in 1925 (a dry season).

5. The capacity of Dhulia Nos. 1 and 2 strains to bear flowers and bolls at an early stage of their growth is very nearly similar to that of N. R. cotton, showing their suitability to Khandesh conditions.

VI. General Conclusions.

The ultimate object of our study of Khandesh cotton is the discovery and multiplication of a type with a staple length of 24 to 25 mm. (one inch) and a ginning percentage of 40 or over, with a yield similar to that given by N. R. cotton. The present memoir shows what progress has been made to this end. It is felt that the capacity of the local cotton to give material tending towards this ideal has been almost exhausted, and that it is only because of the existence of number of lots of seed said to be derived from a cross of Comilla and *Bani* cotton made in 1908 that any serious advance by this method has been achieved. But using this material, and developing pure line cultures from it, it has been possible to get two types at least which bid fair to give longer staple cotton, while preserving the high yielding and high ginning characters associated with N. R. cotton.

It does not seem at all reasonable to suppose that the limit of improvement has been reached, and crosses are now being worked out which, it is hoped, will take us in a very few years much further on the way to the ideal already described.

APPENDIX

Technological Laboratory, Bombay, Spinning test results on Dhulia cottons.

Sample No.	Cotton	Counts nominal	Weight of sample lb.	Waste Percentages: Blow room loss	Waste Percentages: Card room loss	Waste Percentages: Spinning loss	Waste Percentages: Total loss	Spinning Particulars: Card production per hour	Spinning Particulars: Ring frame production per spindle per 10 hrs.	Spinning Particulars: Ring frame yarn breakages per oz. yarn	Spinning Particulars: Ring frame front roller speed R. P. M.	Spinning Particulars: Ring frame front roller diameter Inch	Spinning Particulars: Ring frame draft	Spinning Particulars: Ring frame turns per inch
95-1	(B XX.27) .	20A	20	6·8	5·8	0·8	12·9	..	..	0·32	182	7/8	4·17	16·85
95-2	Dhulia 1 .	20A	20	6·8	5·7	1·0	13·0	..	..	0·31	182	7/8	4·08	16·85
95-1		20B	..	..	..	..	..	..	..	0·27	172	7/8	4·17	17·98
95-2		20B	..	..	..	..	..	..	..	0·16	172	7/8	4·17	17·98
95-1		20C	..	..	..	..	..	..	..	0·90	161	7/8	4·25	19·05
95-2		20C	..	..	..	..	..	..	..	0·16	161	7/8	4·17	19·05
96-1	(B XI.9(34))	20	18	8·8	6·1	0·6	14·8	..	..	0·17	183	7/8	4·44	16·85
96-2	Dhulia 2 .	20	17	8·5	6·0	0·6	14·4	..	..	0·16	183	7/8	4·35	16·85
96-1		30A	..	..	..	..	..	..	..	0·16	141	7/8	6·83	21·86
96-2		30A	..	..	..	..	..	..	..	0·25	141	7/8	6·61	21·86
96-1	..	30B	..	..	..	..	..	..	..	0·08	135	7/8	6·83	23·11
96-2	..	30B	..	..	..	..	..	..	..	0	135	7/8	6·61	23·11
97-1	N. R. . .	10	20	6·9	6·2	0·8	13·5	..	..	0·24	182	7/8	5·41	13·58
97-2		10	20	6·5	6·3	0·9	13·1	..	..	0·15	182	7/8	5·13	13·58
97-1		8	..	..	..	..	..	..	..	0	206	7/8	4·35	12·07
97-2		8	..	..	..	..	..	..	..	0	206	7/8	4·35	12·07

Technological Laboratory, Bombay, Spinning test results on Dhulia cottons.

Sample No.	Cotton	Yarn Test Results							Temperature	Relative Humidity	
		Counts actual	Lea strength lb.	Single thread strength oz.	Single thread irregularity %	Single thread weakness percentage	Turns per inch actual	Single thread extension %	Spinning room °F.	Spinning room %	Testing room %
95-1	(B XX. 27) .	19·1	48·8	9·8	17·7	14·0	17·6	5·8	77	57	60
95-2	Dhulia 1 .	19·1	51·2	10·9	16·4	11·0	17·6	6·4	77	57	68
95-1		19·3	65·6	12·6	11·6	6·0	18·0	6·3	77	57	54
95-2		19·6	59·8	11·6	12·3	5·0	18·0	6·3	77	57	63
95-1		19·5	76·0	12·7	10·8	3·0	17·8	7·0	77	55	60
95-2		18·4	83·9	13·8	9·4	0	19·3	7·3	77	55	68
96-1	(B XI. 9 (34))	19·6	75·2	9·8	8·2	1·0	16·7	6·8	78	57	64
96-2	Dhulia 2 .	19·6	83·0	10·8	8·3	1·0	17·7	6·8	78	57	66
96-1		30·0	44·5	6·0	11·5	3·0	21·1	5·7	78	57	63
96-2		28·4	48·9	6·4	10·6	2·0	20·2	5·8	78	57	57
96-1		29·1	49·1	6·9	10·2	3·0	20·1	6·3	85	64	68
96-2		28·5	49·8	7·2	9·7	3·0	21·1	5·9	85	64	60
97-1	N R. . .	9·7	87·9	15·2	12·3	3·0	14·7	5·8	80	58	58
97-2		9·8	85·2	15·5	11·0	0	14·6	6·3	80	58	56
97-1		7·8	109·8	19·7	9·0	1·0	13·6	6·0	80	58	58
97-2		7·7	127·5	19·8	9·2	0	14·2	6·7	80	58	59

Technological Laboratory, Bombay, Spinning test results on Dhulia cottons.

Sample No.	Cotton	Counts nominal	Weight of sample lb.	Waste Percentages: Blow room loss	Card room loss	Spinning loss	Total loss	Spinning Particulars: Card production per hour	Ring frame production per spindle per 10 hrs.	Ring frame yarn breakages per oz. yarn	Ring frame front roller speed R. P. M.	Ring frame front roller diameter inch	Ring frame draft	Ring frame turns per inch
92-1	B IV. 50	20	20	5·7	5·6	0·4	11·3	..	..	0·09	184	$\frac{7}{8}$	4·17	16·85
92-2		20	20	5·6	5·8	0·3	11·3	..	..	0·05	184	$\frac{7}{8}$	4·25	16·85
92-1		30A	..	..	..	..	..	..	..	0·11	142	$\frac{7}{8}$	6·25	21·86
92-2		30A	..	..	..	..	..	..	..	0·09	142	$\frac{7}{8}$	6·25	21·86
92-1		30B	..	..	..	..	..	..	..	0	135	$\frac{7}{8}$	6·25	23·11
92-2		30B	..	..	..	..	..	..	..	0	135	$\frac{7}{8}$	6·45	23·11
93-1	B XXI	20	20	5·9	5·3	0·4	11·2	..	..	0·12	183	$\frac{7}{8}$	4·35	16·85
93-2		20	20	5·5	5·5	0·5	11·1	..	..	0·18	183	$\frac{7}{8}$	4·44	16·85
93-1		30A	..	..	..	..	..	..	..	0·10	141	$\frac{7}{8}$	6·61	21·86
93-2		30A	..	..	..	..	..	..	..	0·20	141	$\frac{7}{8}$	6·66	21·86
93-1		30·B	..	..	..	..	..	..	..	0·06	134	$\frac{7}{8}$	6·61	23·11
93-2		30B	..	..	..	..	..	..	..	0	134	$\frac{7}{8}$	6·66	23·11
94-1	B XI. 54	10A	5	6·2	8·5	0·8	14·8	..	..	0·13	196	$\frac{7}{8}$	5·55	12·63
94-2		10A	5	5·9	8·3	0·7	14·4	..	..	0·09	196	$\frac{7}{8}$	5·71	12·63
94-1		10B	..	..	..	..	..	..	..	0·04	200	$\frac{7}{8}$	5·26	13·57
94-2		10B	..	..	..	..	..	..	..	0	200	$\frac{7}{8}$	5·41	13·57
94-1		12	..	..	..	..	..	..	..	0·31	181	$\frac{7}{8}$	6·45	14·68
94-2		12	..	..	..	..	..	..	..	0·23	181	$\frac{7}{8}$	6·66	14·68

Technological Laboratory, Bombay, Spinning test results on Dhulia cottons.

Sample No.	Cotton	Yarn Test Results							Temperature	Relative Humidity	
		Counts actual	Lea strength lb.	Single thread strength oz.	Single thread irregularity %	Single thread weakness percentage	Turns per inch actual	Single thread extension %	Spinning room °F.	Spinning room %	Testing room %
92-1	B IV. 50	19·5	73·8	10·0	9·8	0	15·4	4·8	79	63	67
92-2		19·6	75·6	12·3	9·9	0	16·2	4·9	79	63	56
92-1		28·9	44·6	7·2	9·3	0	20·5	4·0	79	63	60
92-2		28·9	43·2	7·7	8·9	0	19·6	4·0	79	63	56
92-1		28·6	54·3	8·0	8·3	0	21·4	4·0	83	66	66
92-2		29·4	48·0	7·6	9·9	1·0	20·2	3·7	83	66	52
93-1	B XXI.	19·2	78·5	10·4	12·0	3·0	15·0	4·8	82	65	59
93-2		20·0	72·0	10·2	8·3	2·0	15·3	4·2	82	65	49
93-1		29·2	45·5	6·2	14·4	8·0	19·9	4·1	82	65	53
93-2		29·3	43·0	6·2	15·3	7·0	20·0	3·6	82	65	51
93-1		29·3	49·7	7·4	10·6	8·0	19·9	3·8	81	59	51
93-2		29·4	44·6	7·3	10·0	8·0	21·0	3·8	81	59	54
94-1	B XI. 54	10·2	94·0	15·1	13·8	8·0	14·7	5·5	81	59	51
94-2		9·9	116·8	17·0	10·0	1·0	14·9	5·6	81	59	52
94-1		9·7	130·9	19·8	10·6	2·0	15·2	5·6	78	55	52
94-2		9·7	133·7	18·9	9·7	2·0	14·7	5·6	78	55	51
94-1		11·8	91·9	16·7	10·5	0	16·0	5·2	78	55	47
94-2		11·9	92·8	14·3	13·9	5·0	16·5	5·5	78	55	60

CONTENTS

THE INDIAN TYPES OF LATHYRUS SATIVUS L.

(*Khesari, lakh, lang, teora*).

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INTRODUCTION.

The vetch, *Lathyrus sativus* L., is cultivated in various parts of India as a cold weather crop. It is chiefly grown in Bombay, Bihar, the Central Provinces, Sind, the Eastern Districts of the United Provinces and in some parts of the Punjab. It is known as *khesari* or *latri* in the North, *lakh* or *teora* in the Central Provinces and *lang* in Bombay. Attempts have been made to connect these various vernacular names with definite botanical types but without success.

Lathyrus sativus L., the pulse of low-lying areas, is a procumbent, rapidly-growing, cold weather annual which requires very little cultivation. It will thrive on heavy clay soils and on recently submerged land where no other pulse will grow. The seed is often scattered on the surface of rice-fields before harvest or it is ploughed in immediately after that crop has been reaped. The grain is generally fed to cattle, but in the poorer districts it takes the place in the food of the people of the better class pulses—*rahar* (*Cajanus indicus* Spreng.) and gram (*Cicer arietinum* L.). In famine years however it is eaten in those localities in which it is normally employed as a fodder. When used for human consumption a form of paralysis, known as lathyrism, occurs. This disease is ascribed by the people themselves to the use of *khesari*. Certain facts, however, seem to call for explanation. Among those who commonly eat *khesari* only a few are affected. The disease is more frequent in famine years, the victims being generally attacked in the monsoon. Moreover, there is a belief among the peasants that only the *khesari* grown in certain districts

produces lathyrism, that from adjoining areas being non-poisonous. In one case, a clear distinction was drawn between the *khesari*, said to be toxic, from the low-lying rice land on one side of a small river, and that from the higher land on the opposite side, which was considered to be innocuous. No botanical differences could be detected between the two crops. Major Buchanan [1] found a similar belief in the Central Provinces, but there the *khesari* on the rice land was said to be harmless, that on the high-lying wheat land poisonous. In this case, however, there was a distinct difference in the appearance of the two sets of seeds.

Many researches into the cause of lathyrism have been undertaken. Most investigators have considered the primary cause to be the consumption of *khesari* for long periods. The majority have attributed the effect to the presence of an alkaloid in the seed (Stockman,[2] Dilling [3]). Acton and Chopra [4] came to the conclusion that the poison occurred in the form of a water-soluble amine. On the other hand Marne [5] and Guillaume,[6] were unable to find any poisonous base in the various species of *Lathyrus* they examined.

In addition to the chemical analyses, a large number of feeding trials on animals have been undertaken with this pulse and with other species of the genus *Lathyrus*. Again discordant results were obtained. Brunelli, Chevallier, Lunier, Proust, Stockman [2] and Acton [4] were able to demostrate a positive correlation. On the other hand, Marne, [1] Liotta, [7] Visco [8] and some of the older writers obtained negative results.

The reasons given for the discrepancies in the chemical results, in the feeding trials and for the sporadic occurrences of lathyrism in the population were (1) the production of variable amounts of toxin in the seed caused by differences in cultivation and storage, (2) individual idosyncracies in susceptibility on the part of animals and persons. The only feature common to all these investigations was the fact that in no case was botanically pure seed used. Owing to the mixed nature of the crop and the universal occurrence in it of various weeds, it is, therefore, impossible to be certain of the nature of the experimental material employed.

The discordant results of the chemical analyses and of the feeding trials led the Indian Research Fund Association in 1923 to initiate a fresh investigation in which the botanical aspect of the problem would receive due weight. A combined study by a medical research officer, a chemist and a botanist was arranged, the work being entrusted to Major L. A. P. Anderson (Central Research Institute, Kasauli), Dr. J. L. Simonsen (then Forest Research Chemist, Dehra Dun) and Mr. A. Howard

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1 Watt, The Commercial Products of India, London, 1908, p. 705.
2 Stockman, *Ed n. Med. Jour.*, xix, 1917, p. 277.
3 Dilling, *Jour. Pharm. and Exp. Therap.*, xiv, 1920, p. 359.
4 Acton & Chopra, *Ind. Med. Gaz.*, lvii, 1922, p. 412.
4 Acton, *Ind. Med. Gaz.*, lvii, 1922, p. 241.
5 Jahns, *Arch. d. Pharm.*, 1897, p. 156.
6 Guillaume, *Bull. Sciences Pharmacol.*, xxx, 1923, p. 604.
7 Liotta, *Arch. Farm. speri. e. Science affini*, xxxiv, 1922, p. 1.
8 Visco, *Arch. Form. speri. e. Science affini*, xxxvii, 1924, p. 269.

(then Imperial Economic Botanist, Pusa). The results obtained have been recorded in two papers,[1] which have been published in *The Indian Journal of Medical Research.*

Bazar samples of seed from all the localities in India in which lathyrism is common were first collected. The botanical examination of these samples showed that *khesari*, as ordinarily grown is by no means a uniform product. A large number of forms of *khesari* were found, several often occurring in the same sample. The grain was also badly contaminated by the seed of various weeds; this extensive contamination being due to the procumbent habit of the plant and to the fact that little or no cultivation is given. A botanical separation of the constituents was then undertaken and a supply of *khesari*, free from all weeds, was obtained for the chemical investigation and for the feeding trials. Contrary to expectation, nc alkaloids were found in *khesari* by chemical analysis. Further, the feeding trials with seed of the pure crop produced no ill effects on animals.

Among the leguminous seeds isolated from the *khesari* samples, four weeds appeared to be fairly common. One of these known as *akta* (*Vicia sativa* L. var. *angustifolia*) was found in all the samples from every locality in which the disease occurred. The seeds of this weed very closely resemble those of immature *khesari*. To obtain uncontaminated seed of *akta*, undehisced pods were collected from plants growing in the neighbourhood of Pusa and this weed was grown in pure culture the following year. The resulting seed was examined chemically and was employed in the feeding trials. Chemical analysis demonstrated the presence of the poisonous alkaloid divicin. When fed to animals these seeds produced symptoms of poisoning similar to, though not identical with, the symptoms of lathyrism in man. Inoculation experiments with divicin gave similar results to those obtained in the feeding trials.

The other three leguminous weeds: *langra khesari* (*Lathyrus sphaericus* Retz.), *misya* (*Vicia hirsuta* Koch.) and *pipra* (*Lathyrus aphaca* L.) were examined chemically and were also fed to animals. No poisonous substances were found in any of these weeds. All three proved to be innocuous in the feeding trials in spite of the vernacular name given to the first weed, which suggests that it might be the real cause of lathyrism.

The investigation is still in progress[2], but so far all the results appear to exonerate the actual pulse crop and to incriminate the weed *akta*.

The studies described in this paper arose out of the above investigation on lathyrism. At the time when the pulse itself was considered to be the cause of the disease it seemed probable that the unit species of *khesari* would differ in their alkaloidal

[1] Howard A., J. L. Simonsen and L. A. P. Anderson. *The Indian Journal of Medical Research*, x, 3, 1923, p. 857.
Anderson, L. A. P., A. Howard and J. L. Simonsen. *Ibid*, xii, 4, 1925, p. 613.

[1] Owing to the absence from India on long leave of Major Anderson I. M. S., the feeding trials are being continued by Colonel McCarrison, I.M.S., at the Pasteur Research Institute, Coonoor.

content. In order to have material of a definite botanical character for the feeding trials, the isolation of the various elementary species in the mixed crop was necessary. The collection of the bazar samples was therefore handed over to us for the separation and description of the unit species. Fifty-six different elementary species were isolated and are described in the following pages. These will be kept in pure culture until the investigation on the cause of lathyrism is completed.

The types isolated from the various bazar samples are shown in the following table :—

TABLE I.

Bazar samples of Indian khesari.

Name of district	Local name	General character of the seed	Types isolated at Pusa
		BOMBAY	
Broach	Lang .	Two samples :—	
		(1) medium sized, grey, mottled . . .	32
		(2) large, black.	
		SIND	
Larkana		Two samples :—	
		(1) small, grey, very mixed . . .	23, 24
		(2) small, black	41, 56
Jacobabad . . .		Small, grey, very mixed	10, 21, 51
		CENTRAL PROVINCES	
Nagpur	Lakh .	Medium sized, grey, mottled, mixed . .	17
Bhandara . . .	Lac .	Large, mottled	35
Jubbulpur . . .		Two samples :—	
		(1) medium sized, grey, mottled . .	13
		(2) medium to small, grey, heavily mottled.	4, 5, 31
Hoshangabad . . .	Teora .	Seven samples :—	
		(1) large, mottled, grey	15
		(2) Ditto	36
		(3) Ditto	..

Bazar samples of Indian khesari—contd.

Name of district	Local name	General character of the seed	Types isolated at Pusa
		CENTRAL PROVINCES.	
Hoshangabad . . .	Teora .	(4) large, mottled, grey . . .	20
	Lac .	(5) medium sized, grey, mottled . .	..
		(6) Ditto . . .	18
		(7) Ditto . . .	28
Narsingpur . . .		Three samples :—	
		(1) medium sized, grey, mottled . .	
		(2) medium sized, grey, mixed . .	45, 46, 48
		(3) large, grey, mottled . . .	1, 30
Saugor	Teora .	Medium to large, mottled . .	..
		BIHAR AND ORISSA	
Hayaghat . . .	Khesari .	Very small, grey, mottled, mixed . .	11, 25, 27
Sakri	,,	Ditto . .	8, 12, 55
Benipur	,,	Ditto . .	22, 50
Darbhanga . . .	,,	Ditto . .	40, 51
Dholi	,,	Ditto . .	26, 38, 39, 43
		UNITED PROVINCES	
Azamgarh . . .	Latri .	Small white, mottled	3, 6, 54
Partabgarh . . .		Small, grey, very mixed	14, 47, 53
Allahabad . . .		Two samples :— (1) medium sized, grey, very mixed	16, 29, 33
		(2) Ditto . .	2, 19, 37, 44
		PUNJAB	
D. G. Khan . . .		Small, grey, very mixed . . .	7, 9, 42, 52

II. GENERAL BIOLOGY.

1. Root Range.

The unit species described in this paper were grown for several years in pure culture at Pusa, the seed being always raised under bag. Seed from single plants was sown for the purposes of classification. In addition, small plots of all the types grown from the mixed seed of several bagged plants were maintained. These were arranged according to their geographical distribution, an arrangement which brought to light the following interesting facts illustrating the relation between the incidence of disease and the condition of the host. *Lathyrus sativus* L. is susceptible to the attacks of *Aphis* and every year this pest occurred in the experimental cultures at Pusa. It was found, however, that only those varieties that came from Peninsular India were badly attacked. The varieties from the Indo-Gangetic Plain were untouched, while those from stations between the Peninsula and the Plains only suffered slightly. Examination of the roots showed that three types of root system occurred. All the immune varieties possessed the shallow much-branched root system characteristic of crops which thrive in the damp soils of the alluvium. The susceptible types belonging to the Peninsula produced a deep root system, branching some distance below the surface. Types intermediate in their resistance to *Aphis* possessed root-systems of an intermediate type. A deep root system, although admirably adapted for growth in the black cotton soils where deep cracks occur in the cold weather, is a serious disadvantage in the close, damp soils of Bihar. When grown in this locality the active roots of the Peninsular types were formed in the badly aerated, wet soil six inches below the surface where no aeration by subsequent cracking was possible. Hence the roots and the whole metabolism of the plant suffered, rendering the plants more susceptible to insect attack. These two types of root-development are well shown in Figure 1.

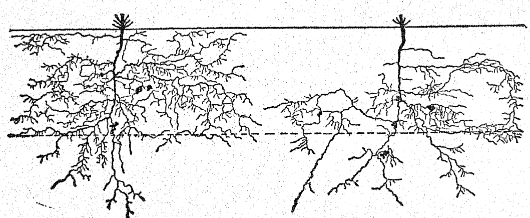

Fig. 1. Root systems of disease-resistant (left) and susceptible (right) types of *Lathyrus sativus* L.

2. Flowering.

A study of the flowering was made at Pusa in the Indo-Gangetic plain and at Indore on the black soils of the Malwa plateau. Although, as would be expected, the general behaviour of the flowers was the same at both places, some minor differences were observed. These were due partly to the fact that at Indore the crop was sown late in the season and partly to the low humidity of that place.

The following observations were made at Pusa during January, 1924. The flower buds begin to open between 10 A.M. and 4 P.M. If opening starts before 2 P.M., the buds open fully on the same day. If, however, opening begins after 2 P.M. the flower may not be fully open by 5 P.M. the time of day when closing normally begins. All the partly or fully open flowers, close at night and re-open the next morning between 9 and 10 A.M. *i.e.* a little earlier than the new buds open. Older flowers however, do not close completely at night. Some exceptional flowers do not close at all during the night. On cloudy and cold days, opening begins later and closing takes place earlier. The flowers continue to close and re-open for three to five days, after which the corolla fades. Sixty-eight flowers in six different types were kept under observation from 20-1-24 to 28-1-24. Among the sixty-eight, two flowers were abnormal, thirteen opened for three days only, twenty-six opened for four days and twenty-seven opened for five days.

The newly-opened flower is smaller in size and lighter in colour than the more mature flower. On the second or third day it reaches its full development and at that time the colour of the corolla is deepest. On the third or fourth day the corolla begins to fade. The breadth of the standard on the day on which the flower first opens varies from 1·3 to 1·6 cm. It increases gradually until the corolla fades, the maximum breadth being 1·8 to 2·1 cm.

The following observations were made at Indore during the early part of March, 1927. Four to five flowers on each of Types 1, 10, 11, 12, 13, 43, 50, 51 and 55 were examined every hour for eight days. During the first few days all the flowers closed at night and re-opened in the morning. On the 12th March, however, a sudden rise in temperature occurred. Observations subsequent to this date showed a change in the flowering. The flowers of Types 2-10 (red or pink corollas) remained open all night. The flowers in Type 1 (white corolla) closed at night in the normal manner. In the types with blue corollas some flowers closed at night, some remained open.

The time of opening of the individual flowers was earlier at Indore than at Pusa, probably again a temperature effect. Well-developed flower buds began to open at about 8 A.M. and were fully open by about noon. Young buds take the whole day for development and often begin to open at 4 P.M. After 4 P.M. they open no further but remain quiescent till morning when they become fully open in about three hours. All flowers which had been open the previous day began to open at

sunrise (6 A.M.) taking about two and a half to three hours to open. The flowers generally remain open for about forty-eight hours before fading begins. As at Pusa the standard increases in breadth after the opening of the flower, but to a less extent.

3. Pollination.

In his *Handbook of Flower Pollination* (Vol. II., p. 334) Knuth describes the method of fertilization in *Lathyrus sativus* L. The observations made at Pusa confirm this description.

" Kirchner gives the following account of the bright blue or white flowers of this species. ('*Flora v. Stuttgart* ;' pp. 511-12.) The claw of the large vexillum grasps the bases of the alae from above only. It is, however, attached to them very firmly, for its base possesses two pairs of folds placed almost at right angles to one another and projecting inwards, so as to fit closely into corresponding depressions of the alae. The front edge of the carina is strengthened by a wing-like appendage and is curved like an S, in such a way that its end lies somewhat to the left. The tip of the right carinal petal is arched outwards, while the left one has a deep terminal fold, in front of which the style lies in the carina. As in *Pisum* the alae ~~are firmly~~ united with the carina, the right ala, however, where it lies above the carinal tip, possesses a dilated fold contracted from above downwards, through which the end of the style, with its small stigma, projects when the carina is depressed. The style broadens above and is compressed from before backwards, but it is turned through an angle of 90° in such a way that its morphological inner side, which bears collecting hairs directed obliquely upwards, is directed to the left and its hairless outer surface to the right. The anthers dehisce in the bud, and discharge their pollen into the stylar brush, by which it is transferred to insect visitors.

Visitors. Kirchner observed the honey bee on cultivated plants in Wurtemberg. When it settled in the middle of the flower it was dusted with pollen behind the head on the right side and regularly effected cross-pollination. It frequently stole nectar by thrusting its proboscis into the right side of the flower, occasionally touching the style with its feet."

At Pusa the anthers burst in the bud some time before the opening of the flower. self-pollination generally taking place. Bees visit the flowers in fairly large numbers from 10 A.M. to 5 P.M. Seed is freely set under bag. These observations were confirmed at Indore. The anthers burst in the bud just as the keel and wings appear. Bees and other insects visit the flowers during the latter part of the day. Seed is freely set under bag.

4. Cross-fertilization.

As the anthers burst before the bud is open, self-fertilization appears to be the normal procedure. Cross-fertilization is, however, sometimes brought about by

the visits of bees and other insects. As these insects only visit the flowers some time after the normal opening, it is probable that crossing only takes place when the pollen of the flower visited is abnormal.

That crossing does take place in India was observed in 1910 at Pusa. In a plot raised from local seed it was found that, while the great majority of plants had blue flowers, a few aberrant plants with pink or red flowers occurred. Ten single aberrant plants were sown in October, 1909. Nine of these split giving pink and blue flowers. Only one red-flowered plant bred true as regards flower colour. In 1924, the single plant cultures of Types 1, 6 and 8 grown from seed bagged in 1923 were quite uniform. Seed from bagged and unbagged plants of these cultures was again grown in 1925. The seed from the bagged plants gave a uniform progeny, true to type. The seed from the unbagged plants of these Types (1, 6, 8) produced a mixed progeny as follows :—

(1) Type 1, a white flowered variety, produced 81 plants with white flowers and 1 plant with blue flowers.
(2) Type 6, with pale pink flowers, produced 511 pale pink and 14 blue-flowered plants.
(3) Type 8, possessing light red flowers, produced 691 light red, 2 pink and 77 blue-flowered plants.

Some interesting cases of variation in the colour of the corolla in flowers on the same plant were made both at Pusa and at Indore. At Pusa in Type 8 (corolla light red) a plant was observed on which there were four branches with red flowers and two branches with blue flowers. A similar case was seen at Indore in 1927 but in the white-flowered variety, Type 1. In a culture of 80 plants three were found to have blue flowers and white flowers on the same branch. The blue flowers resembled those of typical blue-flowered *khesari i.e.*, they showed a certain amount of crimson. In the first plant, two secondary branches of the same primary branch produced flowers of both colours. On the first, there were two blue flowers and one white flower, on the second, one entirely white flower, one white flower with blue spots on the standard and four blue flowers. The other branches of the plant produced white flowers only. In the second plant, one of the primary branches produced three blue flowers and two white flowers with blue spots on the apex of the standard. Three white flowers with blue spots and two entirely white flowers were borne on a side branch. The rest of the plant had white flowers only. In the third plant with coloured flowers, three white flowers with blue spots occurred near the apex of one of the primary branches, the rest of the flowers on the plant were pure white. In all cases, the coloured flowers and the white flowers on the same branch were bagged and will be grown in 1927.

III. CLASSIFICATION AND DESCRIPTION OF THE TYPES.

In the sample of *khesari* examined it has been possible to distinguish fifty-six unit species. The chief morphological characters in which these types differ are :—(1) colour of the flower, (2) presence or absence of red pigmentation on the green pods, (3) colour and mottling of the seed coats. All these characters have been utilized in the classification. Further morphological differences exist in the pigmentation of the vegetative organs and their degree of pubescence. These characters are, however, not very useful for diagnosis as they vary with the age of the structure. Differences in habit, period of growth, tone of colour and size of the leaves were also observed.

The fifty-six unit species have been grouped into three varieties according to the colour of their flowers :—

var. *albus* with white flowers—one type.
var. *roseus* with pink or red flowers—ten types.
var. *cyaneus* with blue flowers—forty-five types.

1. Notes on the characters.

Period of growth. There is a great difference between the types in regard to the time of flowering as measured by the opening of the first flower. In Pusa in 1923-24 the earliest type began to flower on December 24th, the latest on January 27th. At Indore in 1927, the first type flowered on January 18th, the last on February 21st, the crop having been sown somewhat late in the season. In both cases the difference between the earliest and latest flowering types was about a month, a somewhat wide range for so short-lived a crop. Owing to the fact that maturation is often hastened by hot dry winds the difference between the times of ripening of the pods is not great.

Habit. In the young stage all the types are more or less spreading in their habit and run over the ground. Towards flowering time there is a general tendency to become more erect but the amount by which the various types raise themselves varies considerably. In general the types from the Gangetic Plain are more spreading, whereas the types of Peninsular India which form larger plants are more inclined to be upright. When the pods are ripening all the types straggle and become semi-erect.

Vegetative organs—stems, leaves and stipules. The tone of colour varies from yellowish green to dark blue green, the latter often being rendered still darker by the presence of red colouring matter. Two types (1 and 31) are distinctly yellow in tone, fourteen may be described as light green, the rest show a blue green tone. These distinctions are best seen at flowering time. In some types a certain amount of red is found. This may occur on any or all the vegetative structures ; its presence and

the amount varying in the different types. Generally speaking, more red is found on the younger structures than on the old and there is often a marked diminution during the life of the plant. Sometimes the colour is diffused over the whole structure as in the leaves of Type 3. In most cases, however, it is found in linear patches on the stems and petioles or on the margins of the leaves or stipules. The variation in this character with the age of the plant makes it of small diagnostic value.

Another character of the vegetative organs to which some attention has been paid is the presence of fairly long hairs on the stems, petioles and stipules. This character is best observed on the younger portions of the plant. The hairs are generally found on the margins of the stipules and on the four angles of the quadrangular stem.

Flowers. The colour of the flower is sufficiently distinct to be of definite value in distinguishing the types. In addition to white, three distinct tones of colour occur—blue, pink varying in intensity to crimson, and red (Plate I). Purple tones are formed by the superposition of pink on blue. In Type 1 the general colour of the flower is white, in Types 2-11 pink or red with only patches of blue, in the rest blue. These differences are sufficient to justify the creation of three varieties. In the blue flowers the ground of the standard is blue with prominent veins (which are really crimson but appear purple) and a large white eye with or without a pink or crimson margin. The differentiation of the large number of types with a blue standard presented some difficulty, but distinct differences were found in the colour of the back of the standard. In some it is purple with or without crimson patches, in others it is practically crimson. On the back of the standard the crimson colour of the veins shows well. There are no appreciable differences in the size or shape of the flower. The standard increases in size in the period during which the flower is open but this is common to all types.

Pods. The green tone of the pods is similar to that of the vegetative organs. In certain of the types very definite red splashes or markings appear on the sides of the pods (Plate II). These markings are not present in the very young stage but make their appearance during the growth of the pod. The presence or absence of these markings is a definite diagnostic character. There are also distinct differences in size between the markings of the various types. On account of their susceptibility to the environment *i.e.* intensity of sunlight and age of the pod these differences in size have no classificatory value. In addition to these definite markings the mature pods in practically al the types show some diffused purple colouration. This colour is always found on the winged dorsal suture and generally extends over the side. The amount of colour varies with the age of the pod, the exposure to sunlight and with the type. As this pigmentation is present to some extent in practically all the unit species and is very susceptible to the effect of the environment it cannot be used to differentiate the types and has been omitted in the descriptions. The two pigmentations described above are quite distinct; it is impossible to confuse the definite red markings with the diffused purple patches.

Seed. The seeds of *khesari* have a characteristic angular shape when well grown. They vary in size and in the colour of the seed coat, which may be of various shades of grey or of fawn. In some cases the seed coat looks black to the naked eye but this apparently uniform black colour is found on examination to be due to very heavy mottling, the colour of the seed coat being really grey.

All the types with coloured flowers produce seed with mottling or marbling on the seed coat (Plate III). This mottling is visible to the naked eye and appears to be of varying intensity. It is a useful character in differentiating the types as it is constant in colour and pattern.

To facilitate description three grades of mottling visible to the naked eye have been distinguished :—

Grade 1. The general appearance of the seed coat is uniform. This may be due to the fact that no mottling is present or to the fact that the mottling is so heavy as to be almost continuous.

Grade 2. The general appearance is uneven to the naked eye but the mottling does not stand out as spots.

Grade 3. The seed coat appears even to the naked eye to be covered with distinct spots.

When the mottling is examined under a lens it is found that three quite distinct patterns are present. These may all occur together or any one of the three may be present alone. All the three patterns occur in two colours—brown and black. These three forms are useful in differentiating the types. For the sake of convenience they have been termed (1) cloudy mottling, (2) speckled mottling, (3) belt marking.

Cloudy mottling. This consists of a more or less continuous pattern (somewhat like Chinese cloud bands) over the surface of the seed. The bands composing the pattern are formed by minute dots which are scattered so that the ground colour is visible between them. These dots may be (1) black and close together when the mottling is termed *black*, (2) black and sparse when the mottling is termed *blackish* or (3) *brown* (light brown, red brown or dark brown). In five types two cloudy mottlings are present, one blackish and one brown. These two patterns are superposed in most places on the seed but not everywhere.

Speckled mottling. This term is used to describe the occurrence of spots of deep colour which occur irregularly on the seed coats. The colour in them is continuous and not in minute dots as in the cloudy mottling. These spots may be black or of various shades of brown. They may be very sparse (only one or two per seed) or very numerous.

Belt marking. In nearly all the seeds a ring or belt of colour starts from the hilum dividing the seed into two parts. This belt never completely encircles the seed. The line is generally black but a brown belt was found in some types. The colour on the belt is continuous except in a few cases where the line is broken.

2. Key to the Indian Types of Lathyrus sativus L.

I. Flowers white. var. *albus*. Type 1.

II. Flowers pink or red. var. *roseus*.

A. Pods without markings.

1. Flowers pink . . . . Type 2.
2. Flowers pink with some blue patches . . . Type 3.
3. Flowers purplish pink with much blue . . . Type 4.
4. Flowers crimson . . . . Type 5.

B. Pods with red markings.

1. Flowers pale pink and white . . . . . Type 6.
2. Flowers pink with some blue . . . . . Type 7.
3. Flowers light red . . . . Type 8.
4. Flowers deep pink

a. Seed medium in size.

(1) Seed black . . . . . Type 9.

(2) Seed grey with black mottling (cloudy mottling blackish; speckled mottling black) . . Type 10.

(3) Seed fawn with brown mottling (cloudy mottling brown; speckled mottling black) . Type 11.

III. Flowers blue. var. *cyaneus*.

1. Back of standard purple.

A. Pods without markings.

a. Seed small . . . . Type 12.

b. Seed medium in size.

(1) Seed light grey with light mottling (cloudy mottling light brown; speckled mottling black, sparse) Type 13.

(2) Seed light fawn, fairly heavily mottled (cloudy mottling brown; speckled mottling black) Type 14.

(3) Seed dark coloured on account of the very heavy mottling (cloudy mottling dark brown; speckled mottling black, very sparse) . . Type 15.

c. Seed large.

(1) Seed pale brown with distinct reddish brown mottling (cloudy mottling light brown; speckled mottling dark brown) . . . . . Type 16.

(2) Seed grey with distinct black mottling (cloudy mottling blackish; speckled mottling black) Type 17.

(3) Seed purple with indistinct mottling (cloudy mottling dark brown; speckled mottling dark brown) Type 18.

(4) Seed fawn with distinct black mottling (cloudy mottling light brown; speckled mottling black) Type 19.

(5) Seed reddish brown with indistinct dark brown mottling (cloudy mottling light brown; speckled mottling reddish brown) . . . Type 20.

B. Pods with red markings.

a. Seed medium in size.

(1) Seed black (cloudy mottling black covering the whole ground; speckled mottling black, sparse) Type 21.

(2) Seed grey with light mottling (cloudy mottling brown; speckled mottling absent) . Type 22.

(3) Seed pale yellowish brown with a moderate amount of mottling (cloudy mottling brown; speckled mottling black) . . . . . Type 23i

(4) Seed fawn with very heavy black mottling (cloudy mottling blackish; speckled mottling black) Type 24.

2. Back of standard bluish purple with crimson splashes.

A. Pods without markings.

a. Seed small.

(1) Seed fawn (cloudy mottling absent; speckled mottling black, sparse) . . . . . Type 25.

(2) Seed fawn with distinct brown mottling (cloudy mottling reddish brown; speckled mottling absent) . . . . Type 26.

b. Seed medium in size.

(1) Seed fawn with heavy brown mottling (cloudy mottling light brown; speckled mottling dark brown, very sparse) . . . Type 27.

(2) Seed purplish grey, mottling not very distinct (cloudy mottling dark brown; speckled mottling dark brown) . . . . . . Type 28.

(3) Seed reddish fawn with heavy mottling (cloudy mottling blackish; speckled mottling black) Type 29.

(4) Seed grey with indistinct mottling (cloudy mottling blackish; speckled mottling black) . Type 30.

(5) Seed dark grey with heavy mottling (cloudy mottling dark brown; speckled mottling black) Type 31.

c. Seed large.

(1) Seed greenish fawn, mottling sparse (cloudy mottling absent; speckled mottling black) . Type 32.

(2) Seed uniform purplish black, (cloudy mottling blackish covering the whole ground; speckled mottling black) . . . . . . Type 33.

(3) Seed pale fawn with heavy mottling (cloudy mottling dark brown; speckled mottling black) Type 34.

(4) Seed yellow with very heavy mottling

cloudy mottling brown . Type 35
cloudy mottling blackish . Type 36.

(5) Seed grey with distinct mottling (cloudy mottling blackish; speckled mottling black) . Type 37.

B. Pods with red markings.

a. Seed small.

(1) Seed pale reddish fawn, mottling indistinct (cloudy mottling pale brown; speckled mottling absent)

belt marking conspicuous . Type 38.
belt marking indistinct . Type 40.

(2) Seed grey, mottling indistinct, belt marking conspicuous (cloudy mottling of two types, light brown and blackish; speckled mottling black, very sparse) . . . . . Type 39.

(3) Seed grey with heavy mottling, belt markings inconspicuous

cloudy mottling of two types, brown and black . . . . Type 41.

cloudy mottling blackish . . Type 42.

3. Back of standard crimson.

A. Pods without markings.

a. Seed small.

(1) Seed reddish fawn, mottling indistinct (cloudy mottling reddish brown; speckled mottling absent) Type 43.

b. Seed medium in size.

(1) Seed reddish fawn, mottling indistinct (cloudy mottling brown; speckled mottling black) Type 45.

c. Seed large.

(1) Seed uniform black (cloudy mottling black covering the whole ground; speckled mottling black, sparse) Type 44.

(2) Seed grey with heavy mottling (cloudy mottling blackish; speckled mottling black, sparse) Type 46.

(3) Seed yellowish fawn, mottling distinct (cloudy mottling of two types brown and blackish; speckled mottling black) . . . . . Type 47.

(4) Seed pale greyish fawn, mottling indistinct (cloudy mottling light brown; speckled mottling black) Type 48.

B. Pods with red markings.

a. Seed small.

(1) Seed reddish fawn, mottling indistinct (cloudy mottling brown).

seed reddish fawn; speckled mottling absent Type 49.

seed pale reddish fawn; speckled mottling dark brown . . . Type 50.

(2) Seed light grey, mottling indistinct (cloudy mottling of two types, brown and blackish; speckled mottling black) . . . . Type 51.

(3) Seed yellow with very distinct black mottling (cloudy mottling of two types, brown and blackish; speckled mottling black) . . Type 52.

b. Seed medium.

(1) Seed pale fawn, belt marking conspicuous (cloudy mottling brown; speckled mottling black)

mottling inconspicuous . . Type 53.

mottling distinct . . . Type 54.

(2) Seed reddish fawn, heavily mottled (cloudy mottling blackish; speckled mottling black sparse) Type 55.

(3) Seed grey, fairly heavily mottled (cloudy mottling of two types, brown and blackish; speckled mottling absent) . . . . Type 56.

3. Description of the Types.

var. *albus*.

Type 1. Medium in maturity, (3-1-24).[1] *Leaves* yellowish green, (5·7 ×0·5 cm.[2]). No red on the stems or stipules. Hairs numerous on the stems and stipules, few on the petioles. *Flowers* white; standard white with yellow veins; wings and keel white. *Pods* without markings. *Seed* medium in size; ground colour greenish fawn; no mottling of any kind.

var. *roseus*.

Type 2. Very early (24-12-23). *Leaves* blue green, (5·2×0·5 cm.). A little red on the stems and stipules. No hairs on the stems, petioles or stipules. *Flowers* pink; standard pink, veins yellow on the back and deep pink on the front, eye white and small; wings pink; keel white with a little pink. *Pods* without markings. *Seed* large; ground colour reddish fawn; mottling grade 1; cloudy mottling light brown; speckled mottling brown, sparse; belt marking black, continuous.

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[1] Date of opening of the first flower.

[2] Average length and breadth of the leaflets measured at Pusa in 1924.

TYPE 3. Medium in maturity (6-1-24), less vigorous than Type 6. *Leaves* red in the seedling stage, dark reddish green at flowering time, (5·7×0·4 cm.). Much red on the stems and stipules. *Flowers* pale pink with a few blue patches; standard pink in front with a few blue patches near the somewhat large white eye, veins pink on the front, yellow on the back; wings pink; keel white with a little pink. *Pods* without markings. *Seed* small; ground colour fawn; mottling grade 1; cloudy mottling brown; speckled mottling black, sparse; belt marking black, continuous.

TYPE 4. Medium in maturity (7-1-24), habit somewhat erect. *Leaves* somewhat light green, (5·1×0·4 cm.). No red on the stems or stipules. Hairs numerous on the stems and stipules, few on the petioles. *Flowers* purplish pink with a good deal of blue; standard purplish pink with much blue near the large white eye, veins prominent; wings purplish pink with diffused blue colour on the margin; keel white with some pink. *Pods* without markings. *Seed* small; ground colour fawn; mottling grade 3; cloudy mottling in two colours brown and blackish; speckled mottling black; belt marking black, discontinuous.

TYPE 5. Medium in maturity (3-1-24). *Leaves* light green, (5·4×0·4 cm.). A little red on the stems and stipules. Hairs numerous on the stems and stipules, few on the petioles. *Flowers* crimson; standard crimson with some blue patches round the eye, veins prominent; wings crimson; keel white with a good deal of pink. *Pods* without markings. *Seed* small; ground colour fawn; mottling grade 3; cloudy mottling pale brown; speckled mottling dark brown; belt marking black, continuous.

TYPE 6. Medium in maturity (4-1-24), more vigorous than Type 3 which it resembles. *Leaves* blue green, (6·4×0·7 cm.), lighter in colour and broader than in Type 3. Some red on the stipules, none on the stems. Practically no hairs on the stems or petioles, a fair number on the stipules. *Flowers* pale pink; standard pale pink fading to white near the large white eye, veins yellow; wings pale pink; keel white with some pale pink. *Pods* with red markings. *Seed* medium in size; ground colour fawn; mottling grade 2; cloudy mottling brown; speckled mottling black; belt marking black, continuous.

TYPE 7. Very late (21-1-24). *Leaves* blue green, (4·2×0·4 cm.). No red on the stems or stipules. No hairs on the stems, petioles or stipules. *Flowers* pink; standard pink with a blue edge, veins crimson on the front, yellowish on the back, eye white and large; wings pink; keel practically white. *Pods* with red markings. *Seed* medium in size; ground colour grey; mottling grade 2; cloudy mottling brown; speckled mottling black, sparse; belt marking reddish brown, continuous.

TYPE 8. Medium in maturity (7-1-24). *Leaves* light green, (5·0×0·5 cm.). No red on the stems or stipules. Hairs few on the stems, numerous on the petioles and stipules. *Flowers* light red; standard light red with deep red veins, eye small and white with a little blue on the margin; wings light red; keel practically white. *Pods* with red markings. *Seed* small, ground colour reddish fawn; mottling grade 2;

cloudy mottling reddish brown; speckled mottling reddish brown; belt marking reddish brown, continuous.

TYPE 9. Very late (19-1-24). *Leaves* blue green, (3·5×0·4 cm.). Much red on the stems and stipules. Some hairs on the stems, petioles and stipules. *Flowers* deep pink; standard deep pink in front lighter on the back, veins prominent, eye with a little blue on the margin; wings deep pink; keel white with a little pink. *Pods* with red markings. *Seed* medium in size; ground colour grey, but appears blac on account of the heavy mottling; mottling grade 1; cloudy mottling black covering the whole ground; speckled mottling black, sparse, hardly visible; belt marking black, continuous.

TYPE 10. Late (14-1-24). *Leaves* dark blue green, (4·5×0·4 cm.). Much red on the stems and stipules. No hairs on the stems and petioles, many on the stipules. *Flowers* deep pink; standard deep pink in front, lighter on the back, veins not prominent, eye white with a little blue on the margin; wings deep pink; keel white with a little pink. *Pods* with red markings. *Seed* medium in size; ground colour grey; mottling grade 3; cloudy mottling blackish; speckled mottling black; belt marking black, continuous.

TYPE 11. Very late (28-1-24). *Leaves* blue green, (5·7×0 6 cm.). No red on the stems or stipules. Numerous hairs on the stems, petioles and stipules. *Flowers* deep pink, standard deep pink in front, lighter on the back, veins somewhat prominent, eye white with a little blue on the margin; wings deep pink; keel white with a little pink. *Pods* with red markings. *Seed* medium in size; ground colour fawn; mottling grade 2; cloudy mottling brown; speckled mottling black; belt marking black, continuous.

var. *cyaneus*.

TYPE 12. Very late (25-1-24). *Leaves* a somewhat dark blue green, (4·7×0·4cm.). Much red on the stems and stipules. Numerous hairs on the stems, petioles and stipules. *Flowers* blue; standard blue in front and purple at the back, with much crimson, veins prominent, eye white with a pink border; wings pink below, blue above; keel white with some pink. *Pods* without markings. *Seed* small; ground colour fawn; mottling grade 2; cloudy mottling light brown; speckled mottling black; belt marking black, discontinuous.

TYPE 13. Medium in maturity (3-1-24), habit somewhat erect. *Leaves* blue green, (4·7×0·4 cm.). No red on the stems, a little on the stipules. Hairs few on the stems; numerous on the petioles and stipules. *Flowers* blue; standard blue with a crimson tinge in front, purple at the back, veins crimson, eye white with a pink margin; wings blue above, pink below; keel white with some pink. *Pods* without markings. *Seed* medium in size; ground colour grey; mottling grade 2; cloudy mottling light brown; speckled mottling black, sparse; belt marking black, continuous.

TYPE 14. Late (9-1-24). *Leaves* blue green, (6·3×0·6 cm.). No red on the stems or stipules. Numerous hairs on the stems, petioles and stipules. *Flowers* blue; standard blue in front, light purple at the back, eye white with a pink border, veins crimson; wings blue above, pink below; keel white with some pink. *Pods* without markings. *Seed* medium in size; ground colour fawn; mottling grade 3; cloudy mottling brown; speckled mottling black; belt marking black, continuous.

TYPE 15. Early (24-12-23). *Leaves* light green, (5·6×0·6 cm.). A little red on the stems and stipules. No hairs on the stems or petioles, a few on the stipules. *Flowers* blue; standard blue in front and purple at the back, veins crimson, prominent, eye white with a pink border; wings blue above; pink below; keel white with some pink. *Pods* without markings. *Seed* medium to large; ground colour fawn; mottling grade 3; cloudy mottling dark brown; speckled mottling black, very sparse; belt marking black, continuous.

TYPE 16. Early (30-12-23). *Leaves* light green, (6·0×0·5 cm.). A little red on the stems, none on the stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front, purple at the back with much crimson, veins crimson, prominent, eye white with a pink border; wings blue above, pink below; keel white with a little pink. *Pods* without markings. *Seed* medium in size; ground colour reddish fawn; mottling grade 2; cloudy mottling light brown; speckled mottling dark brown; belt marking very dark brown, continuous.

TYPE 17. Early (24-12-23), habit spreading and open. *Leaves* blue green with a good deal of red, (5·2×0·4 cm.). Much red on the stems and stipules. Hairs numerous on the stems, few on the petioles and stipules. *Flowers* blue; standard deep blue in front, deep purple at the back, but with so much diffused crimson as to make it appear almost crimson, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with a good deal of pink. *Pods* without markings. *Seed* large; ground colour grey; mottling grade 3; cloudy mottling blackish; speckled mottling black; belt markings black, continuous.

TYPE 18. Very early (24-12-23), vigorous. *Leaves* light green, (5·8×0·5 cm.). No red on the stems or stipules. A few hairs on the stems, petioles and stipules. *Flowers* blue; standard blue in front, purple at the back, veins crimson, eye white with a pink border; wings blue above, pink below; keel pink in front and white at the back. *Pods* without markings. *Seed* large; ground colour fawn; mottling grade 1; cloudy mottling dark brown; speckled mottling dark brown, sparse; belt marking black, discontinuous.

TYPE 19. Medium in maturity (7-1-24). *Leaves* blue green, (5·3×0·6 cm.). No trace of red on the stems or stipules. Hairs numerous on the stems, few on the petioles and stipules. *Flowers* pale blue; standard light blue in front verging to pink at the sides, light purple at the back, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with some pink. *Pods* without markings. *Seed* large; ground colour fawn; mottling grade 2; cloudy mottling light brown; speckled mottling black; belt marking black, continuous.

Type 20. Very early (24-12-23). *Leaves* light green, (7·8 $\times$ 0·5 cm.). No trace of red on the stems or stipules. Hairs numerous on the stems and stipules, absent on the petioles. *Flowers* blue ; standard blue in front and purple at the back with some crimson, veins crimson, prominent, eye white with a crimson border ; wings blue above, pink below ; keel white with some pink. *Pods* without markings. *Seed* large ; ground colour reddish fawn ; mottling grade 1 ; cloudy mottling light brown ; speckled mottling reddish brown ; belt marking very dark brown, continuous.

Type 21. Very late (25-1-24). *Leaves* light green, (4·3 $\times$ 0·5 cm.). A very little red on the stems and stipules. A few hairs on the stems, petioles and stipules. *Flowers* blue ; standard deep blue in front and purple at the back, veins crimson, prominent, eye white with crimson border ; wings blue above, pink below ; keel white with a little pink. *Pods* with red markings. *Seed* small ; ground colour grey, but the seed appears black on account of the heavy mottling ; mottling grade 1 ; cloudy mottling black covering the whole ground ; speckled mottling black, very sparse ; no belt marking.

Type 22. Very late (18-1-24). *Leaves* blue green, (5·4 $\times$ 0·7 cm.). Much red on the stems and stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue ; standard deep blue in front and purple at the back, veins crimson, eye white with a pink border ; wings blue above, pink below ; keel white with some pink. *Pods* with red markings. *Seed* medium in size ; ground colour greenish grey ; mottling grade 2 ; cloudy mottling brown ; speckled mottling absent ; belt marking black, discontinuous.

Type 23. Very late (19-1-24). *Leaves* blue green, (4·3 $\times$ 0·6 cm.). Much red on the stems and stipules . Hairs fairly numerous on the stems, petioles and stipules. *Flowers* blue ; standard blue in front and purple at the back with much crimson, veins crimson, very prominent, eye white with a pink border ; wings blue above, pink below ; keel white with some pink. *Pods* with red markings. *Seed* medium in size, ground colour fawn ; mottling grade 2 ; cloudy mottling brown ; speckled mottling black ; belt markings black, continuous.

Type 24. Very late (28-1-24). *Leaves* light blue green with some red, (4·4 $\times$ 0·5 cm.). Much red on the stems and stipules. Some hairs on the stems and petioles, a few on the stipules. *Flowers* blue ; standard deep blue in front, purple at the back, veins crimson, eye white with a pink border ; wings blue above, pink below ; keel white with some pink. *Pods* with red markings. *Seed* medium in size ; ground colour fawn ; mottling grade 3 ; cloudy mottling blackish brown ; speckled mottling black ; belt marking black, continuous.

Type 25. Late (13-1-24). *Leaves* blue green, (5·4 $\times$ 0·5 cm.). A little red on the stipules, none on the stems. Hairs numerous on the stems, petioles and stipules. *Flowers* blue ; standard blue in front, light purple at the back, veins crimson, eye white with a pink border ; wings blue above, pink below ; keel white with a little pink. *Pods* without markings. *Seed* small ; ground colour fawn ; mottling grade 1 ; cloudy

mottling absent; speckled mottling black, very sparse; belt marking black in separate dots.

Type 26. Late (14-1-24). *Leaves* light blue green, (5·4×0·7 cm.). A little red on the stems, much on the stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front, light purple at the back with some crimson patches, veins crimson, prominent; wings blue above, pink below; keel white with a little pink. *Pods* without markings. *Seed* small; ground colour fawn; mottling grade 3; cloudy mottling reddish brown; speckled mottling absent; belt marking black, continuous.

Type 27. Late (13-1-24). *Leaves* dark blue green with much red, (5·2×0·6 cm.). A good deal of red on the stems and stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard deep blue in front, deep purple at the back with some crimson, veins crimson, prominent; eye white with a pink border; wings blue above, pink below; keel white with a little pink. *Pods* without markings. *Seed* medium in size; ground colour fawn; mottling grade 2; cloudy mottling light brown; speckled mottling dark brown, very sparse; belt marking black, continuous.

Type 28. Very early (24-12-23). *Leaves* light green, (4·6×0·5 cm.). A little red on the stems and stipules. Only a few hairs on the stems and stipules, none on the petioles. *Flowers* blue; standard blue in front, almost crimson at the back, veins crimson, eye white with a crimson border; wings blue above, pink below; keel white with a little pink. *Pods* without markings. *Seed* medium in size; ground colour grey; mottling grade 2; cloudy mottling dark brown; speckled mottling dark brown; belt markings black, continuous.

Type 29. Early (27-12-23). *Leaves* light green, (5·6×0·5 cm.). Very little red on the stems and stipules. Hairs fairly numerous on the stems and stipules, none on the petioles. *Flowers* blue; standard blue in front and light purple at the back with a good deal of diffused crimson, eye white with a crimson border; wings blue above, pink below; keel white with a little pink. *Pods* without markings. *Seed* medium in size; ground colour reddish fawn; mottling grade 3; cloudy mottling blackish; speckled mottling black; belt marking black, continuous.

Type 30. Early (24-12-23). *Leaves* light green, (5·7×0·6 cm.). No red on the stems or stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front, light purple at the back with much crimson, veins crimson, eye white with a crimson border; wings blue above, pink below; keel white with a little pink. *Pods* without markings. *Seed* medium in size; ground colour yellowish grey; mottling grade 2; cloudy mottling blackish; speckled mottling black, sparse; belt marking black, continuous.

Type 31. Late (10-1-24), habit somewhat erect. *Leaves* yellowish green, (4·9×0·5 cm.). No red on the stems or stipules. A few hairs on the stems and petioles, many on the stipules. *Flowers* blue; standard blue in front, light purple at the back with a good deal of crimson, veins crimson, eye white with a crimson border; wings blue above, pink below; keel white with a little pink. *Pods* without markings.

Seed medium in size; ground colour fawn; mottling grade 3; cloudy mottling dark brown; speckled mottling black; belt marking black, continuous.

Type 32. Early (26-12-23), habit somewhat erect. *Leaves* blue green, (5·5×0·5 cm.). Very little red on the stems and stipules. Hairs few on the stems and petioles, numerous on the stipules. *Flowers* blue; standard blue in front, purple at the back with some crimson, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with a little pink. *Pods* without markings. *Seed* large; ground colour fawn; mottling grade 2; cloudy mottling absent; speckled mottling black; belt marking black, continuous.

Type 33. Early (26-12-23). *Leaves* blue green, (5·7×0·6 cm.). No red on the stems and stipules. Hairs numerous on the stems and stipules, very few on the petioles. *Flowers* blue; standard blue in front, light purple at the back, veins crimson, prominent, eye white with a pink border; wings blue above, pink below; keel pink above, white below. *Pods* without markings. *Seed* large; ground colour grey, the seed however appears black on account of the heavy mottling; mottling grade 1; cloudy mottling blackish covering the whole ground; speckled mottling black; belt marking black, continuous.

Type 34. Early (27-12-23). *Leaves* light green, (5·0×0·5 cm.). Very little red on the stems, more on the stipules. Only a few hairs on the stems and stipules, none on the petioles. *Flowers* blue; standard blue in front, purple at the back with much crimson, veins crimson, prominent, eye white with a pink border; wings blue above, pink below; keel white with a little pink. *Pods* without markings. *Seed* large; ground colour grey; mottling grade 3; cloudy mottling dark brown; speckled mottling black; belt marking black, discontinuous.

Type 35. Early (24-12-24), habit somewhat erect. *Leaves* light blue green, (4·9×0·4 cm.). No red on the stems or stipules. Hairs few on the stems and petioles, fairly numerous on the stipules. *Flowers* blue; standard blue in front, purple at the back, veins crimson, eye white with a crimson border; wings blue above, pink below; keel white with a little pink. *Pods* without markings. *Seed* large; ground colour grey; mottling grade 3; cloudy mottling dark brown; speckled mottling black; belt marking black, continuous.

Type 36. Very early (24-12-23). *Leaves* light green, (5·1×0·4 cm.). Some red on the stems, none on the stipules. No hairs on the stems or petioles, a few on the stipules. *Flowers* blue; standard deep blue in front, deep purple at the back, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with a little pink. *Pods* without markings. *Seed* large; ground colour fawn; mottling grade 3; cloudy mottling blackish; speckled mottling black; belt marking black, continuous.

Type 37. Early (24-12-23). *Leaves* blue green, (6·5×0·8 cm.). No red on the stems or stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue standard blue in front, purple at the back, veins crimson, eye white with a pink border wings blue above, pink below; keel white with some pink. *Pods*

without markings. *Seed* large; ground colour grey; mottling grade 3; cloudy mottling blackish; speckled mottling black; belt marking black, continuous.

TYPE 38. Medium in maturity (4-1-24). *Leaves* blue green, (5·1×0·5 cm.). No red on the stems or stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard deep blue in front and deep purple at the back, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with a little pink. *Pods* with red markings. *Seed* small; ground colour fawn; mottling grade 2; cloudy mottling light brown; speckled mottling absent; belt marking black, continuous.

TYPE 39. Medium in maturity (3-1-24). *Leaves* dark blue green, (5·3×0·5 cm.). Very little red on the stems and stipules. Hairs fairly numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front and light purple at the back, veins crimson, prominent, eye white with a pink border; wings blue above, pink below; keel white with a little pink. *Pods* with red markings. *Seed* small; ground colour grey; mottling grade 2; two types of cloudy mottling superposed light brown and blackish; speckled mottling black, very sparse; belt marking black, continuous.

TYPE 40. Very late (22-1-24). *Leaves* light green, (5·3×0·6 cm.). A little red on the stems, much on the stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front, purple at the back but with so much diffused crimson as to make it appear almost crimson; veins crimson, eye white with a pink border, wings blue above, pink below; keel white with a little pink. *Pods* with red markings. *Seed* medium in size; ground colour fawn; mottling grade 2; cloudy mottling reddish brown; speckled mottling absent; belt marking slight, black, discontinuous.

TYPE 41. Very late (25-1-24). *Leaves* light green, (3·7×0·5 cm.). Very little red on the stems or stipules. Some hairs on the stems, petioles and stipules. *Flowers* blue; standard blue in front, purple at the back with some diffused crimson, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with some pink. *Pods* with red markings. *Seed* small; ground colour grey; mottling grade 3; two types of cloudy mottling superposed, one blackish, the other red brown; speckled mottling black; belt markings black, continuous.

TYPE 42. Very late (29-1-24). *Leaves* blue green, (4·6×0·5 cm.). Much red on the stems and stipules. Some hairs on the stems, petioles and stipules. *Flowers* blue; standard blue in front, purple at the back with some diffused crimson, veins somewhat dark, eye white with a pink border; wings blue above, pink below; keel white with a small amount of pink. *Pods* with red markings. *Seed* small; ground colour grey; mottling grade 3; cloudy mottling blackish; speckled mottling black; belt marking black, continuous.

TYPE 43. Medium in maturity (3-1-24). *Leaves* dark blue green, (5·4×0·6 cm.). A little red on the stems and stipules. Hairs numerous on the stems, petioles and

stipules. *Flowers* blue; standard blue in front, crimson at the back, veins crimson, eye white with deep crimson border; wings pink below, blue above; keel white with some pink. *Pods* without markings. *Seed* small; ground colour fawn; mottling grade 2; cloudy mottling reddish brown; speckled mottling absent; belt marking black, continuous.

TYPE 44. Very early (24-12-23). *Leaves* light blue green, (5·8×0·6 cm.). No red on the stems or stipules. A few hairs on the stems and petioles, many on the stipules. *Flowers* blue; standard blue in front, somewhat lighter in tone than in Types 45, 46, 47 and 48, crimson at the back, but not so deep as in some types, veins crimson, eye white with pink border; wings blue above, pink below; keel white with some pink. *Pods* without markings. *Seed* large; ground colour grey only visible with a lens; mottling grade 1; cloudy mottling black covering the whole ground; speckled mottling black, very sparse; belt marking black, continuous but almost invisible owing to the heavy cloudy mottling.

TYPE 45. Early (26-12-23). *Leaves* light green, (5·5×0·5 cm.). A little red on the stems, none on the stipules. Hairs numerous on the stems and stipules, few on the petioles. *Flowers* blue; standard blue in front and crimson at the back, veins crimson, eye white with crimson border; wings blue above and pink below; keel white with some pink. *Pods* without markings. *Seed* medium in size; ground colour fawn; mottling grade 2; cloudy mottling brown; speckled mottling black; belt marking black, continuous.

TYPE 46. Very early (24-12-23). *Leaves* light green, (5·1×0·5 cm.). No red on the stems, very little on the stipules. A few hairs on the stems and petioles, many on the stipules. *Flowers* blue; standard blue in front and crimson at the back, veins crimson, eye white with a pink border; wings blue above and pink below; keel white with some pink. *Pods* without markings. *Seed* large; ground colour fawn; mottling grade 3; cloudy mottling blackish; speckled mottling black, sparse; belt marking black, continuous.

TYPE 47. Medium in maturity (5-1-24). *Leaves* light blue green, (5·4×0·7 cm.). No red on the stems or stipules. No hairs on the stems or petioles, many on the stipules. *Flowers* blue; standard blue in front, crimson at the back, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with some pink. *Pods* without markings. *Seed* large; ground colour a very pale yellow fawn; mottling grade 3; cloudy mottling of two types superposed brown and blackish; speckled mottling black; belt marking black, continuous.

TYPE 48. Very early (24-12-23); slightly more erect than Type 47. *Leaves* light blue green, (5·4×0·5 cm.). No red on the stems or stipules. A few hairs on the stems, none on the petioles, many on the stipules. *Flowers* blue; standard blue in front and crimson at the back, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with some pink. *Pods* without markings. *Seed* large; ground colour grey; mottling grade 2; cloudy mottling light brown; speckled mottling black, sparse; belt marking black, continuous.

Type 49. Medium in maturity (3-1-24). *Leaves* light blue green, (5·2×0·7 cm.). A little red on the stems, much on the stipules. A few hairs on the stems and petioles, many on the stipules. *Flowers* blue; standard deep blue in front, deep crimson at the back, veins crimson, eye white with much diffused crimson; wings pink below, blue above; keel white with some pink. *Pods* with red markings. *Seed* small; ground colour fawn; mottling grade 2; cloudy mottling dark brown; speckled mottling absent; belt marking black, discontinuous.

Type 50. Early (27-12-23). *Leaves* blue green, (4·9×0·6 cm.). No red on the stems, very little on the stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front, crimson at the back, veins crimson, eye white but with much diffused crimson; wings pink below, blue above; keel white with some pink. *Pods* with red markings. *Seed* small; ground colour fawn; mottling grade 2; cloudy mottling light brown; speckled mottling dark brown; belt marking black, continuous.

Type 51. Very late (16-1-24). *Leaves* blue green, (4·2×0·5 cm.). Much red on the stems and stipules. Some hairs on the stems, petioles and stipules. *Flowers* blue; standard blue in front with patches of crimson at the back, veins crimson, eye white with a crimson border; wings blue above, pink below; keel white with some pink. *Pods* with red markings. *Seed* small; ground colour light grey; mottling grade 2; cloudy mottling of two types light brown and blackish; speckled mottling black; belt marking black, continuous.

Type 52. Late (14-1-24). *Leaves* blue green, (4·0×0·5 cm.). Much red on the stems and stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front, crimson at the back but in patches, veins crimson, eye white with crimson edge; wings blue above, pink below; keel white with some pink. *Pods* with red markings. *Seed* small; ground colour yellow; mottling grade 3; two types of cloudy mottling superposed one reddish brown, the other blackish; speckled mottling black; belt marking black, discontinuous.

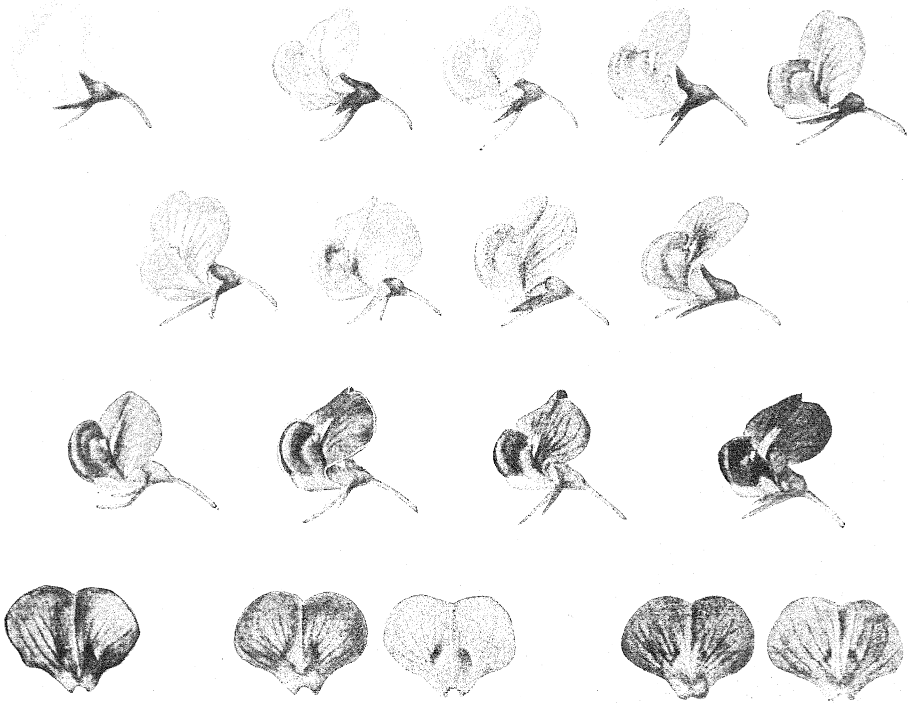
Type 53. Medium in maturity (7-1-24). *Leaves* blue green, (5·1×0 6 cm.). No red on the stems, some on the stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front, crimson at the back, veins crimson, eye white with pink border; wings blue above, pink below; keel white with some pink. *Pods* with red markings. *Seed* medium in size; ground colour fawn; mottling grade 2; cloudy mottling brown; speckled mottling black, sparse; belt marking black, continuous.

Type 54. Medium in maturity (4-1-24). *Leaves* blue green, (5·3×0·5 cm.). Much red on the stems and stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front, crimson at the back but lighter in tone than in Types 51 and 53, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with some pink. *Pods* with red markings. *Seed* medium in size; ground colour fawn; mottling grade 3; cloudy mottling reddish brown; speckled mottling black; belt markings black, continuous.

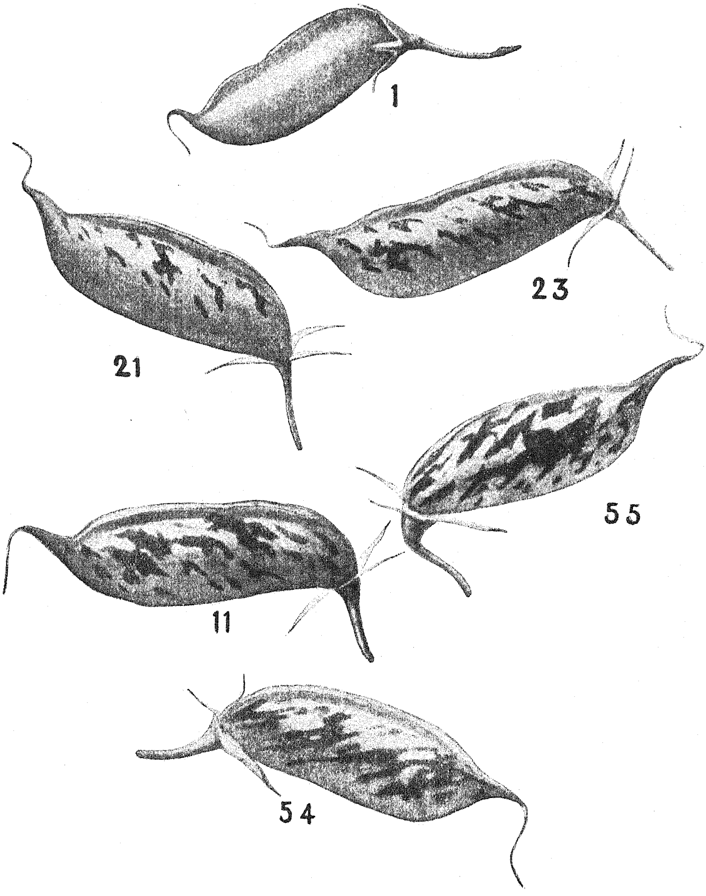
Type 55. Very late (23-1-24). *Leaves* light blue green, (5·3×0·5 cm.). A little red on the stems and stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front, crimson at the back, deeper in colour both on the front and back than in Types 51, 53 and 54, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with much pink. *Pods* with red markings. *Seed* medium in size; ground colour reddish fawn; mottling grade 3; cloudy mottling blackish; speckled mottling black, sparse; belt marking black, continuous.

Type 56. Very late (19-1-24). *Leaves* dark blue green, (4·2×0·5 cm.). Much red on the stems and stipules. Hairs numerous on the stems, petioles and stipules. *Flowers* blue; standard blue in front, crimson at the back, veins crimson, eye white with a pink border; wings blue above, pink below; keel white with much pink. *Pods* with red markings. *Seed* medium in size; ground colour grey; mottling grade 3; two types of cloudy mottling superposed one reddish brown, the other blackish; speckled mottling black, very sparse; belt marking black, continuous.

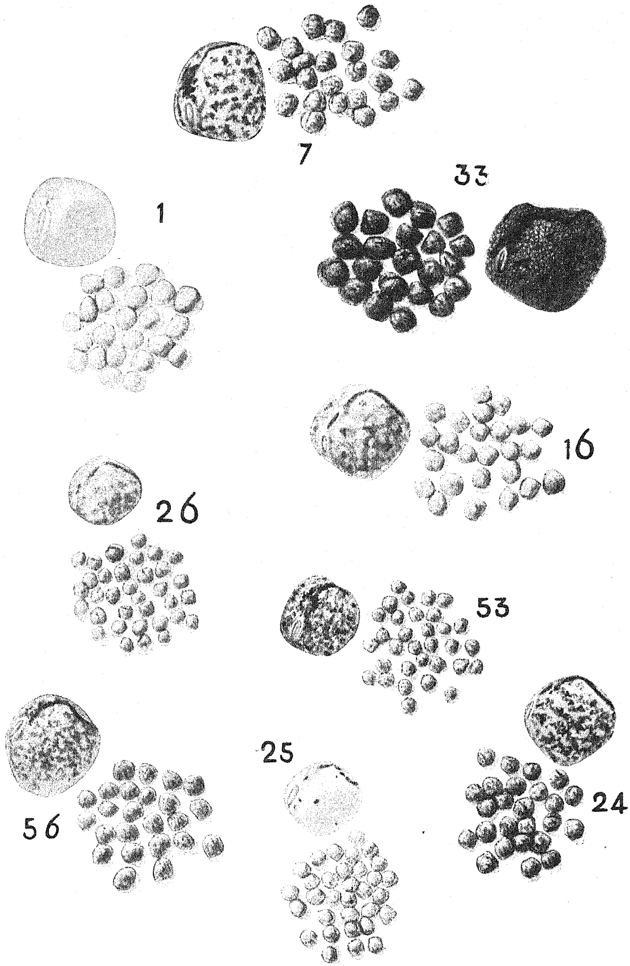
PLATE I.



THE RANGE IN FLOWER COLOUR IN LATHYRUS SATIVUS L.



POD MARKINGS.



SEED-COAT MARKINGS.

FRUIT-ROT DISEASE OF CULTIVATED CUCURBITACEÆ CAUSED BY *PYTHIUM APHANIDERMATUM* (EDS). FITZ.

BY

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(Received for publication on 20th May 1927.)

For the last few years in Pusa during the monsoon a fruit-rot disease of various members of the Cucurbitaceæ has been doing considerable damage to the fruit both in the field and in storage. In 1922 a species of *Pythium* was isolated from *Luffa acutangula* (*tori*), *L. ægyptiaca* (*gheaura*), *Trichosanthes anguina*, L. (snake gourd), *T. dioica* (*parwal*), *Cucumis sativus* (*khira*), *Lagenaria vulgaris* (*kuddo or lauki*), *Momordica Charantia* (*karela*) *and Cucumis Melo* var. *Momordica* (*phut*). All these plants are very important as their fruits are used as vegetables in India.

The fungus is more prominent on fruits than on leaves and stems and forms a luxuriant woolly mycelial weft. The whole fruit appears as if wrapped in absorbent cotton. This external appearance is found on all those host plants which the fungus has been found infecting. The tissues in the interior of the fruits become watery and soft and the decaying matter emits a bad odour. It is common in the field during and after the rains and most of the fruits lying on the soil or hanging near the ground level are attacked. The disease spreads among the fruits when they are in store.

This fungus has also been observed in the United States of America on cucumber and egg plant fruits and has been reported recently by Drechshler [1,2] as doing a considerable amount of damage.

Microscopic examination of affected fruits of these Cucurbitaceæ reveals unseptate mycelium and the mycelium both in the rotten portion and on the surface is

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[1] Drechshler, C. The cottony leak of cucumber caused by *Pythium aphanidermatum* *Journal Agri. Res.*, Vol. XXX, No 11.

[2] Drechshler, C. The cottony leak of egg plant fruits caused by *Pythium aphanidermatum* *Phyto, pathology*, Vol. XVI, p. 16, 1926.

full of oogonia antheridia and oospores. The fungus was isolated and taken into culture by transferring some of the aerial woolly mycelium by means of a sterile needle direct from the specimen found in the field and also by first keeping the infected specimen side by side with a healthy fruit and when the fungus had formed a good growth on the healthy fruit, then transferring a portion of actively growing mycelium to a culture tube.

All the strains grow very well in culture of different kinds, and especially well on oat-meal agar where the fungus forms a good woolly aerial growth full of oogonia and oospores. Sporangia and zoospores are not formed in any medium, but if a little of the culture is put in tap or distilled water in a basin to which some ants killed in boiling water are added, zoosporangia are formed within six hours. The zoosporangium and the mode of discharge of the zoospores are exactly like those of *Pythium* belonging to the *gracile* group. They also resemble Edson's *Rheosporangium aphanidermatum*,[1] a reference to which will be made later on.

Parasitism.

In order to avoid repetition of names, the following letters are adopted to represent various strains and hosts.—

P_1—*Pythium* strain isolated from *Luffa acutangula* H_1
P_2— „ „ „ „ *L. aegyptiaca* H_2
P_3— „ „ „ „ *Trichosanthes anguina* H_3
P_4— „ „ „ „ „ *dioica* H_4
P_5— „ „ „ „ *Cucumis sativus* H_5
P_6— „ „ „ „ *Lagenaria vulgaris* H_6
P_7— „ „ „ „ *Momordica Charantia* H_7
P_8— „ „ „ „ *Cucumis Melo* var. *Momordica* H_8

All the strains isolated were inoculated on their respective hosts and they readily infected and produced woolly aerial growth on the surface and penetrated into the tissue of the fruits causing decomposition and rotting. The re-isolation of these different strains was done and they resembled the original ones found in nature.

Healthy fruits were washed with corrosive sublimate (1 part in 1,000 c.c. of water) and then washed thoroughly with sterile distilled water. Diseased fruits were then kept with these sterilized fruits side by side almost touching in moist chambers and within 24 hours the fungus had passed over to the healthy fruit and in 48 hours had spread and formed a woolly aerial growth almost covering three-fourth of the fruit. In another 24 hours the whole fruit became badly infected and began to give a putrid smell.

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[1] Edson, H. A. *Rheosporangium aphanidermatum*. A new genus and species of fungus parasitic on sugar beets and radishes. *Jour. Agri. Res.*, Vol. IV, No. 4.

Diseased fruits were also kept in a collection of healthy fruits in a room and such of the latter as were in immediate contact with the former became infected in 24 hours and the whole collection became infected and unfit for human consumption in a few days.

The above experiments show that the strains are parasitic on their respective hosts.

Cross-inoculations. All the strains (P_1-P_8) when cross-inoculated on each other's hosts were found to infect those hosts readily.

The inoculation and cross-inoculation experiments prove that all the strains are parasitic and allied to each other.

As all the strains showed a good deal of resemblance with *Pythium Butleri* Subrm.[1], it was decided to cross inoculate all the cucurbit strains on hosts in which *P. Butleri* Subrm. has been recorded, *i.e.* on papaya, chillies, tobacco and ginger and *P. Butleri* on the hosts of cucurbit strains. For this purpose, *P. Butleri* Subrm. was isolated from a diseased papaya plant in the kitchen garden at Pusa.

P. Butleri, when inoculated on the fruits of all the cucurbits, *i.e.*, H_1-H_7, gave successful infection results and formed woolly aerial growth in all cases. The infection spread deep into the tissue and caused rotting.

Cultures of *Pythium* P_1-P_6 were cross inoculated on papaya fruits and were able to infect the papaya, but of these only P_3 gave vigorous growth like that of *P. Butleri*, while the others though they caused infection had only a poor growth.

They were also inoculated on papaya trees, each strain on a separate tree by making a wound at the foot and inserting therein the mycelium containing oogonia and oospores. The wounded places were covered with cotton wool and kept moist. The experiment was carried out thrice. On the first occasion no infection was noticed, though *P. Butleri* produced foot-rot. The second and third experiments were successful. In three days the infection was observed to have spread a good deal, the tissue in some cases became soft to such an extent that the tree was blown down by a slight breeze.

These experiments, though successful, did not give typical symptoms of "foot-rot" as caused by *P. Butleri* on papaya.

The cross-inoculations in chilli failed to give successful infection. In the case of cross-inoculations on tobacco and ginger, the infection took place, but the growth was poor and after a few days the fungus failed to infect a further area.

The results of cross-inoculations on papaya, chillies, tobacco and ginger show that, though these strains are very like *P. Butleri*, they are physiologically a little different and the morphology described below will show that they are allied to *P. Butleri*.

The Tables show details of inoculations carried out :—

[1] Subramaniam, L. S. A Pythium disease of ginger, tobacco and papaya. *Mem. Dept. Agri. India, Bot. ser.*, Vol. X., No. 4.

TABLE I.

Inoculations with Pythium strains P_1-P_6 and P. Butleri on the fruits of H_1-H_6 and on papaya.

Date	Pythium strains	Plants inoculated	Method of inoculation	Results	Control	Control infected	REMARKS
13th August 1922	P_1	Fruits of H_1-H_6	Wounded and unwounded.	+	One fruit of each.	—	
13th August 1922	P_2	Ditto	Ditto	+	Ditto	—	
18th August 1922	P_3	Ditto	Ditto	+	Ditto	—	
18th October 1924	P_4	Ditto	Ditto	+	Ditto	—	
17th October 1922	P_5	Ditto	Ditto	+	Ditto	—	
16th June 1923	P_6	Ditto	Ditto	+	Ditto	—	
24th August 1924	P_3	Ditto	Ditto	+	Ditto	—	
24th August 1924	P_6	Ditto	Ditto	+	Ditto	—	
3rd July 1924	*P. Butleri*	Ditto	Ditto	+	Ditto	—	
1st January 1924	P_1	Fruit of papaya	Ditto	+	Ditto	—	Infection was not vigorous.
1st January 1924	P_2	Ditto	Ditto	+	Ditto	—	Ditto
1st January 1924	P_3	Ditto	Ditto	+	Ditto	—	Ditto
1st January 1924	P_4	Ditto	Ditto	+	Ditto	—	Ditto
1st January 1924	P_5	Ditto	Ditto	+	Ditto	—	Ditto
1st January 1924	P_6	Ditto	Ditto	+	Ditto	—	Ditto
1st January 1924	*P. Butleri*	Ditto	Ditto	+	Ditto	—	Infection vigorous.

TABLE II.

Inoculations with Pythium strains P_1-P_6 and P. Butleri on papaya, chilli, tobacco and ginger plants.

Date	*Pythium* strains	Plants inoculated	Method of inoculation	Result	Control	Result	REMARKS
20th November 1924	P_1-P_6 and *P. Butleri*	Chilli plants Two plants with each strain.	Wounded and unwounded on leaves and at the base of the plant.	..	2	—	
16th August 1925	Ditto	Ditto Six plants with each srain.	In each case three were wounded and three unwounded.	..	6	—	
24th January 1924	Ditto	Papaya plants at the base of stem.	Wounded and unwounded.	*Nil* except those inoculated with *P. Butleri.*	2	—	
28th August 1924	P_3 and P_6	Two papaya plants at the base with each strain.	Wounded	+	1	—	Infection took place but no typical foot-rot was produced as caused by *P. Butleri.*
10th August 1925	P_1-P_6	Ditto	Ditto	+	2	—	Ditto
10th August 1925	*P. Butleri*	One papaya plant.	Ditto	+	1	—	Typical foot-rot.
15th August 1925	P_1-P_6 and *P. Butleri.*	Ginger plants. Two plants for each strain.	Ditto	+	2	—	Very slight infection.
16th October 1924	Ditto	Tobacco. Two seedlings for each strain.	Unwounded	*Nil* except those inoculated with *P. Butleri.*	2	—	

Morphology of the fungus.

The mycelium is composed of much branched hyphæ, the breadth being 2·5—7·5 μ. In old cultures and on the mycelium on old tissues of attacked fruits, irregular septation has been noticed. The growth of the fungus is luxuriant on all meal agars, especially on oat meal agar and it forms a woolly aerial growth. In culture only oogonia and antheridia are formed. In no solid media has sporangial formation been observed, but these sporangia are formed in abundance in water-culture or in boiled ant-culture. Their number increases if a few drops of formic acid are added to the water culture. Irregular swelling of hyphæ rich in protoplasm is noticed in water-culture or on ant-culture. When a little mycelium is transferred to distilled water in a watch glass, it gives rise to stout swollen hyphæ which grow and form bud-like lateral growths, as described by Butler,[1] very rich in protoplasm and sporangia are formed under favourable conditions. Sporangia generally contain 30-45 biciliated zoospores, but the number is very variable ranging from 15 to 60. Sporangia formation in the case of the cucurbit fungus is just like that described in the case of *P. gracile* and *P. Butleri* [2]. Zoospores oogonium and antherdium are like those described by Edson for *Pythium aphanidermatum*.[3]

The antheridia may be terminal or intercalar. Oogonia are formed on short lateral stalks but occasionally they are intercalar. Sporangia and oogonia are formed at temperatures ranging from 20° to 30° C. The following Table shows the measurement of oogonia and oospores :—

Pythium strain's host	Oogonia limits	Oogonia average of 50	Oospores limit	Oospores average of 50
Luffa acutangula	18·7—25·3 μ	23·1 μ	14·3—18·7 μ	16·3 μ
Luffa ægyptiaca	22—25·3 μ	23·4 μ	18·7—20·9 μ	18·5 μ
Trichosanthes anguina, L. . . .	22—28·6 μ	25·5 μ	18·7—22 μ	20 μ
Cucumis sativus	19·8—24·2 μ	21·5 μ	14·3—18·7 μ	16·9 μ
Lageneria Valgaris	19·8—23·1 μ	21·5 μ	16·5—17·6 μ	17·4 μ
Carica Papaya, L. (*P. Butleri*) . .	18—33 μ	26 μ	13·5—25·3 μ	21 μ
P. aphanidermatum	22—27μ	. . μ	17—19 μ	. .

This *Pythium* on Cucurbitaceæ evidently corresponds to a variety of *P. gracile* Schenk, first described by Butler [4] in India and later on changed to *P. Butleri* by

[1] Butler, E. J. An account of the genus Pythium and some Chytridiaceæ *Mem. Dept. Agri. India, Bot. Series*, Vol. I, No. 5.
[2] Subramaniam, L. S. *loc. cit.*
[3] Edson, H. A. *loc cit.*
[4] Butler, E. J. *loc. cit.*

Subramaniam who described its presence on ginger, papaya, tobacco and chillies. A similar fungus has been described by Edson in United States of America, as the cause of a disease of *Raphanus Sativus* and *Beta Vulgaris.* Edson has described his fungus as a new genus of Saprolegniacea and called it *Rheosporangium aphanidermatum.*

Carpenter[1] later on found a fungus on the roots of sugarcane in Hawaii and says that *Rheosporangium aphanidermatum* and *P. Butleri* are identical. Fitzpatrick[2] subsequently changed the name *Rheosporangium* into *Pythium* as Edson was not justified in creating a new genus and named it *Pythium aphanidermatum.*

Drechshler[3] has described recently *P. aphanidermatum* as occurring on cucumbers in United States of America and his description agrees with that of the fungus on various cucurbits in India causing fruit-rot. Pythium aphanidermatum has also been found to be doing considerable damage to chilli seedlings in Pusa and has also been recorded on mustard seedling and potato plants. The results of cross inoculation experiments described above show that *P. Butleri* and *P. aphanidermatum* are very closely allied. *P. aphanidermatum* can infect the hosts on which *P. Butleri* has been found parasitic, but cannot produce typical symptoms of foot-rot on papaya, and the oogonia and oospores of latter are slightly bigger than that of former. Thus *P. Butleri* is a strain of *P. aphanidermatum.*

SUMMARY.

1. *Pythium aphanidermatum* (Eds.) Fitz. has been found doing a considerable damage to various cucurbits which are used in India as vegetables and causes fruit-rot.

2. It has been isolated from *Luffa acutangula*, *L. ægyptiaca*, *Trichosanthes anguina*, *T. dioica*, *Cucumis sativus*, *Lagenaria vulgaris*, *Momordica Charantia* and *Cucumis Melo* var *Momordica.*

3. The results of inoculation and cross-inoculation experiments prove that all strains isolated are identical and that *P. Butleri* Subrm. is a strain of *P. aphanidermatum.*

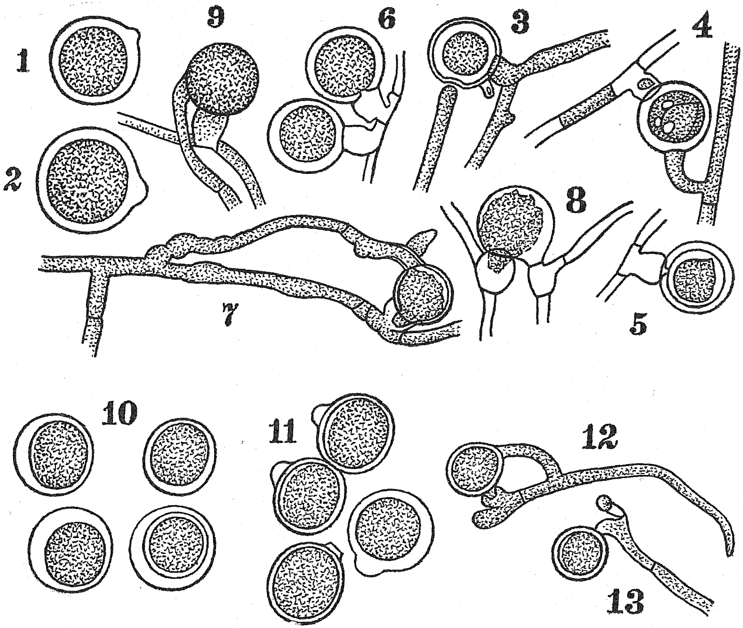
4. The fungus is more prominent on fruits than on leaves and stem and form a luxuriant woolly mycelium weft. The tissues in the interior of the fruits become watery and soft and the decaying matter emits a bad odour.

5. The sporangia formation is like those of *Pythium* belonging to the *gracile* group. The fungus grows very well in cultures of different kind especially on meal agars and forms plenty of oogonia and oospores. The sporangia and zoospores are not formed in any solid media but are formed copiously in water culture or on boiled ants in culture within six hours.

[1] Carpenter, C. W. Morphological studies of the Pythium-like fungus associated with root-rot in Hawaii. *Bull. Expt. Station, Hawaii Suga· Planter's Association, Bot. Series, Vol. III, Part I, 1921.*

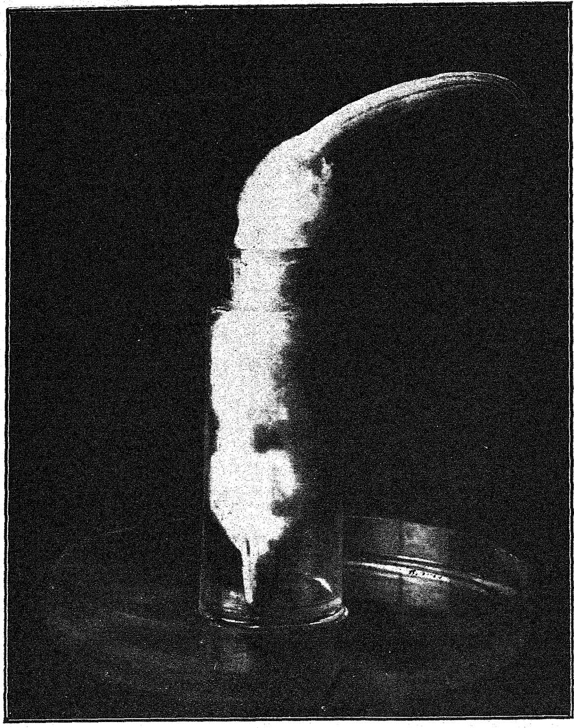
[2] Fitzpatrick, H. M. Generic concepts in the Pythiaceae and Blastocladiaceae, *Mycologia* 15, pp. 166-173.

[3] Drechshler, C. *loc. cit.*

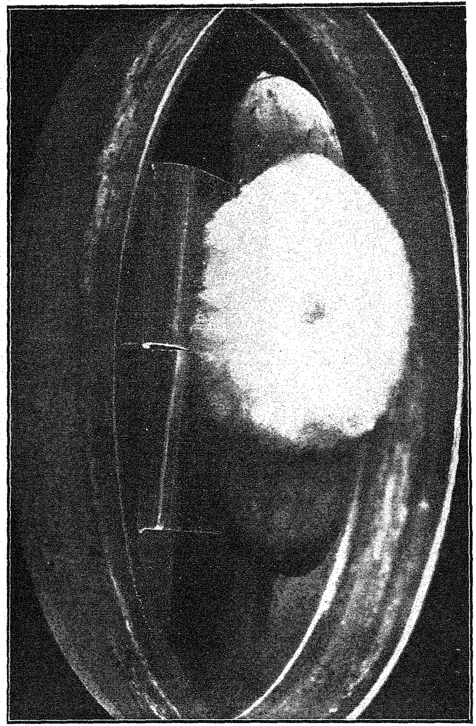


Fruit-rot disease of cucurbitaceae caused by *P. aphanidermatum*.

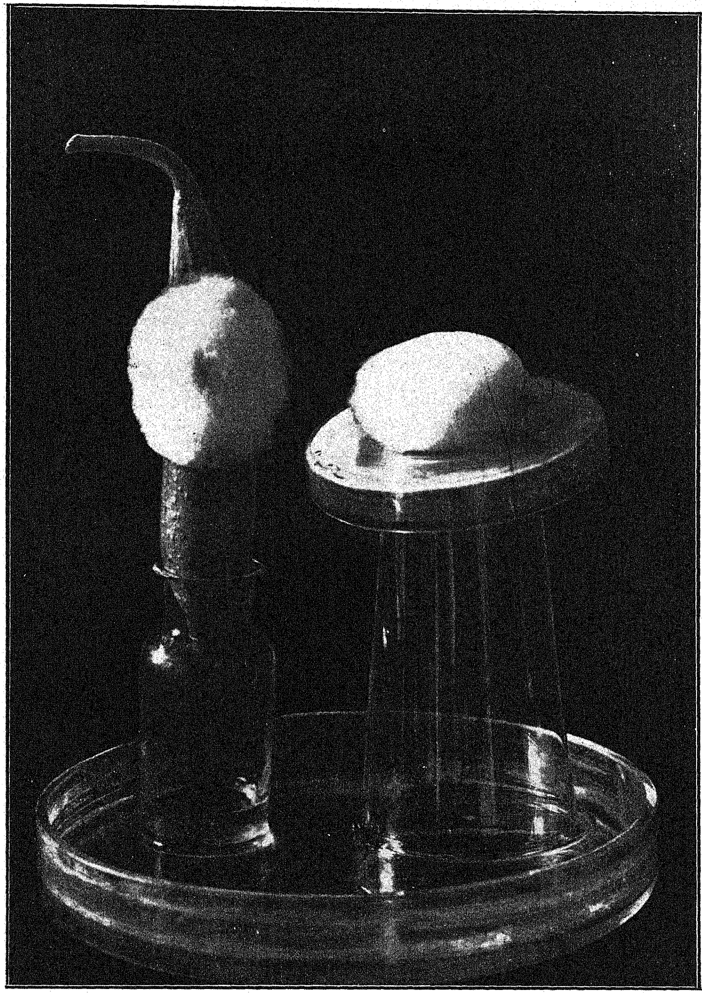
Figs. 1 to 9. *Pythium Butleri* (Papaya strain) ×750.
Figs. 10 to 13. *Pythium aphanidermatum* ×750.



1. *Pythium aphanidermatum* on snake-gourd.



2. *Pythium aphanidermatum* growing on cucumber



Pythium aphanidermatum on *Tori* and *Parwal*.

COLOUR INHERITANCE IN RICE.

BY

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(*Received for publication on 19th April 1927.*)

Among the workers on rice in India, Hector and Parnell have devoted sufficient time to the study of the inheritance of character in rice. They studied the effects of natural cross-fertilization, resulting from the cultivation, side by side, of a large number of different varieties for pure line and selection experiments. According to Hector (1923), cross-fertilization takes place in rice to an extent of about 4 per cent., while Parnell (1917) found it to be between ·1 to 2·9 per cent. with an average of 1·4 per cent. on experimental basis. The observations of the writers show that natural crosses do not occur more than ·5 per cent. on average. This lower percentage of natural crosses in Assam is perhaps due to heavy rains during the *Aus* season and the dewy mornings during the *Sail*, both of which prevent the pollens from being transferred easily.

In their work on cross-fertilization both Hector and Parnell realized the difficulty of working with so many different varieties with their respective colour combinations exhibiting in various parts of the plants as different patterns. As a result of successful investigations they have come to definite conclusions in many interesting phenomena. The writers have been continuing the work on the same line since 1921 and have obtained some definite results which will be discussed in this paper.

In almost all cases reciprocal crosses were tried, but their results were identical. In cases where the resulting F_1 plant exhibited the character of the mother plant, thus indicating that self-fertilization might have occurred, they were discarded. All the crosses were tried on potted plants in the Laboratory verandah, so as to avoid any chance of natural cross-fertilization.

In the work on cross-fertilization with rice, attempt was made to study the inheritance of colour in rice following the standard of Mendelian system of heredity. Such a work on cross-fertilization has a scientific value of its own as well as a direct economic value on the line of genotypic selection, *i.e.*, the breeding of improved pure

strains. It is with this dual purpose in view that attempts were made to try artificial cross-fertilization in *Aus* and *Sail* varieties separately. In all cases only pure types, that have been grown successively under observation for 4 to 5 years or more, were used in crossing.

The study of colour inheritance in rice has been taken up both in connection with the vegetative as well as the floral parts. As the colours involved are various and the type of pattern differs in different varieties, it is not an easy task to describe the situation of colour in each variety. Moreover, no two varieties are found to be alike in respect to their distribution of colour in different parts. For this reason, each individual variety has been chosen in respect to its characteristic colour pattern and crossed with another variety with a colour pattern of its own.

In a number of cases where two plants bearing the same characters were crossed, such as green and green, the progeny in F_1 generation became distinctly coloured which was not visible in any of the parent plants. It appears therefore that of the two green parents each contains such a factor, A or B (with their respective allelomorphic absences a or b), which alone is incapable of expressing the colour. But when these two complementary characters (A and B) combine (AB), we get the colour, or in other words, in the absence of any one of the complementary characters the green colour prevails. They will behave as such in any case of hybridization involving two pairs of typical allelomorphs and give rise to a ratio of 9 : 7 in the F_2 generation.

It has been noticed that in all cases where a colour factor has come out from two non-coloured (green) plants, one of the parent plants has colour in some part of it, although not in the part under consideration. Two entirely non-coloured (green) plants (with no colour in any part) have not been found to produce any colour factor in any part except in one case (cross No. 158). This may lead to the conclusion that the factor that produces the colour exsits in some part of the parent plants in some form or other, or remains masked by other dominant factors for lack of suitable combinations.

In order to study the various simple colour factors that play an important part in the distribution of colour in rice, the main parts of the plant, where the colour is found to be most frequent in the different pure coloured types, are grouped together both in regard to vegetative as well as floral characters, under the following heads :—

Vegetative parts	1.	Colour character in leaf-sheath
	2.	" " " pulvinus
	3.	" " " ligule
	4.	" " " auricle
	5.	" " " internode
Floral parts	6.	" " " outer glume
	7.	" " " inner glume
	8.	" " " tip
	9.	" " " stigma
Mature grain	10.	" " " kernel

As a result of successful crosses in regard to colour characters in the 10 different colour groups, as mentioned above, Mendelian inheritance of colour factors has been discovered in a majority of cases, while some different types of factors have been brought out in others, of which definite evidence has been supplied in each case, except two where clear-cut evidence is wanting.

The colour of rice is found in different parts of the plant as red, yellow, brown, purple, black and different shades of each as light or deep. The pigmented sap, that causes the colour, changes with the vegetative growth of the plant so markedly that in the mature plant majority of the colours disappear except in the mature spikelet. It is in this part that the colour is fixed during maturity. It has been noticed in some cases that the colour which was found in the early part of the plant disappeared with later growth, while with others it appeared in non-coloured plants during their maturity. It has also been noticed that a plant which appears to be slightly coloured, when observed in the field, becomes distinctly coloured when grown in a dry condition, *i.e.*, in a pot or in the dry season. The factors that dominate the changes of colour in different parts are therefore complicated and it seems that there is no general rule that determines the inheritance of colour in the different parts of the plant from germination to maturity.

There is a correlation of colour in the different parts of the rice plant more or less. Some of them are more marked than others. For example, it has been noticed that if the leaf-sheath is coloured, pulvinus may be either coloured or white, though a coloured leaf-sheath has a greater affinity for coloured pulvinus. But, if the leaf-sheath is green, the pulvinus is not found to be coloured. Similarly, the combination of green tip and coloured stigma does not occur although the reverse combination occurs frequently. Hector (1922) has dealt with the correlation of colour in detail and his observations are noteworthy.

In the colour inheritance of rice, some of the colours are dominant over others, such as purple over green or white, red over white, green or yellow over brown, and black over green or yellow. Several cases of incomplete dominance were met with where the dominance is not marked very well in F_2 generation segregating in three distinctly different sets, of which the intermediates are found to be heterozygous in respect to colour character.

In order to determine the number of units and allelomorphic pairs in independent colour units, which are brought out in the resulting crosses in F_2 generation, each particular character will be dealt with separately. It may be pointed out here that the colour complexes are not fixed in a regular manner in any particular part of the plant. For this reason the presence of colour in any form is considered to be coloured in respect to that individual part. Moreover, in case of purple, pink, brown, yellow, red and black colour, they may be present in any shade ranging from light to deep colour. They are determined by independent colour factors and so have been taken separately.

1. Colour character in leaf-sheath.

The colour of leaf-sheath is either green or purple, the latter ranging from light to deep. The colour may be found either inside or outside in long stripes along the vascular bundles, just below the epidermis or all throughout. It may be at the base only, either in the upper or lower surface. In fact, the colour of leaf-sheath is not fixed in a particular part.

Green plants, when crossed, generally produced green leaf-sheath. But exception was found in two strains which on crossing produced coloured leaf-sheath, although their progeny are all green when selfed. On examination, it was noticed that these two strains possess colour in some part though not in the leaf-sheath.

The following Table shows the segregation of colour in F_2 generation of 9 families :—

Table I.

Segregation of colour of leaf-sheath in F_2 generation.

Cross No.	Parent varieties	No. of plants	Light purple	Purple	Deep purple	Green	Observed ratio	Theoretical ratio
1	M-$\frac{36}{30}$ Green × As.-$\frac{15}{5}$ Deep purple.	146	..	..	111	35	3·2 : 1	3 : 1
6	As. 3 Green × As. -$\frac{14}{3}$ Deep purple.	149	..	..	119	30	4·0 : 1	„
16	S. 127 Green × S. B. 136 Purple.	91	..	65	..	26	2·5 : 1	„
54	S. 22 Green × S. 154 Purple.	156	..	126	..	30	4·2 : 1	„
99	S. 22 Green × S. 314 Deep purple.	125	..	..	100	25	4·0 : 1	„
188	S. 22 Green × S. $\frac{158}{3}$ Light purple.	181	141	..	..	40	3·5 : 1	„
192	S. 33 Purple × S. 14 green	140	..	94	..	46	2·0 : 1	„
158	S. 152 Green × S. 14 Green	139	75	..	..	64	1·2 : 1	1·3 : 1
57	S. $\frac{232}{1}$ Green × S. 15 Green.	125	95	..	..	30	3·2 : 1	3 : 1

Table I shows clearly that the factors for purple are always dominant over the green, in all cases of leaf-sheath, and they segregate in the Mendelian ratio of 3 : 1, more or less, in every case except in No. 158, where two green parents brought out a coloured dominant type in F_1, which was not present in the parents. The coloured F_1 plants, being self-fertilized, produced an F_2 generation segregating in the ratio of 1·2 : 1. Thus the total progeny in F_2 consisted of plants bearing nine-sixteenths coloured leaf-sheath and seven-sixteenths green leaf-sheath. The light purple colour is due to the interaction of two separate factors. Neither of these two factors was in itself able to bring out the colour, but a combination of two complementary green factors was essential in expressing the factor for light purple colour which become dominant. If the complementary characters are designated as A and B and their respective allelomorphic absences as a and b, the genetic constitution in F_2 may be stated as follows :—

Parents	Green			AAbb	
	Green			aaBB	
F_1	Light purple			AaBb	
F_2	Light purple			Green	
	AB	—	Ab—	aB—	ab
	9	:	3 :	3 :	1
Theoretical ratio . .			9 : 7		

The raising of the F_3 generation showed a number of pure strains from both coloured and non-coloured (green) plants. Accordingly, out of the 75 coloured plants only 7 came out as pure in the F_3 generation in the ratio of 9·7 : 1, while among the 64 green plants only 35 were found to be pure, the ratio between heterozygotes and homozygotes being 1 : 1·2.

The results in this case are similar to that found by Bateson (1905) in sweet peas where coloured forms appeared from white × white in the ratio of 9 coloured and 7 white, which proved that the colour depends on the co-existence of two complementary factors in the individual.

Parnell (1917) obtained confirmatory evidence of the existence of two pigmentation factors in a cross between two non-coloured plants from which a pigmented type appeared.

In No. 57 both the parent plants have green leaf-sheath and as in No. 158 the expected ratio would have been 9 : 7, whereas the ratio found is 3·17 coloured : 1 non-coloured of which an explanation is wanting. But, it may also be mentioned here that one of the parents S.15 in No. 57 has coloured inner glumes. It is perhaps due to assortment of combinations that the factor for colour in the leaf-sheath is thus brought out in the simple 3 : 1 ratio.

2. Colour character in pulvinus.

The colour of pulvinus is either white or purple. It may be found on both sides, in the centre only, or all throughout. The following Table will show the segregation of colour in F_2 generation of 9 families :—

Table II.

Segregation of colour of pulvinus in F_2 generation.

Cross No.	Parent varieties	No. of plants	Light purple	Purple	Deep purple	White green	Observed ratio	Theoretical ratio
1	M $\frac{36}{30}$ White green × As. $\frac{15}{5}$ Purple.	146 (F_1 Light purple).	..	112	..	34	3·3 : 1	3 : 1
6	As. 3 White green × As. $\frac{14}{3}$ Purple.	149	..	118	..	31	3·8 : 1	,,
16	S. 127 White green × S. B. 136 Light purple.	91	65	..	..	26	2·5 : 1	,,
54	S. 22 White green × S. 154 Light purple.	158	119	..	..	39	3·1 : 1	,,
99	S. 22 White green × S. 314 Deep purple.	125	..	..	100	25	4·0 : 1	,,
192	S. 33 Purple × S. 14 White green.	140	.	111	..	29	3·8 :1	,,
57	S. $\frac{232}{1}$ White green × S. 15 White green.	120	72	..	..	48	1·5 : 1	1·3 : 1
158	S. 152 White green × S. 14 White green.	138	68	..	..	70	1 : 1·0	,,
188	S. 22 White green × S. $\frac{158}{3}$ White green.	181	104	..	..	77	1·4 : 1	,,

From Table II it is evident that Nos. 1, 6, 16, 54, 99 and 192 bear a relation similar to the ordinary ratio of 3 : 1, whereas Nos. 57, 158 and 188 segregate in the ratios approximating the theoretical ratio 1·3 : 1, as has already been discussed in No. 158, Table 1. Moreover, in No. 1 the purple colour of the parent becomes dominant as light purple (intermediate) in F_1. But the segregation in F_2 brings out the purple colour as usual and the light purple colour does not appear at all. The reason of this delayed dominance remains unexplained.

3. Colour character in ligule.

The colour of ligule is either white green or purple and is expressed either on the tip of the bristles, at the base or all throughout. The Table below shows the segregation of colour in F_2 generation of 8 families :—

Table III.

Segregation of colour of ligule in F_2 generation.

Cross No.	Parent varieties	No. of plants	Light purple	Purple	Deep purple	White green	Observed ratio	Theoretical ratio
1	M $\frac{36}{30}$ White green × As. $\frac{15}{5}$ Purple	146	..	110	..	36	3·1 : 1	3 : 1
6	As. 3 White green × As. $\frac{14}{3}$ Purple.	149	..	115	..	34	3·4 : 1	"
16	S. 127 White green × S. B. 136 Light purple.	91	65	..	..	26	2·5 : 1	"
54	S. 22 White green × S. 154 Light purple.	158	119	..	..	39	3·1 : 1	"
99	S. 22 White green × S. 314 Deep purple.	125	..	..	99	26	3·8 : 1	"
192	S. 33 Purple × S. 14 White green.	140	..	..	90	50	1·8 : 1	1·3 : 1
158	S. 152 White green × S. 14 White green.	138	74	..	..	64	1·2 : 1	"
188	S. 22 White green × S. $\frac{158}{3}$ White green.	181	104	..	..	77	1·4 : 1	"

Table III shows clearly that Nos. 1, 6, 16, 54 and 99 follow the simple ratio of 3 : 1 respectively, while Nos. 158 and 188 approach the theoretical ratio of 1·3 : 1, as has been explained in No. 158, Table I. As regards No. 192, the ratio we expect is 3 : 1, but as a matter of fact the observed ratio does not come out to be so.

The result in this case, like the segregation in No. 158, Table I, may also be explained on the basis of two independent pairs of factors, but the type of interaction

between them is somewhat different, for no new colour appears in F_1 and F_2. The purple colour occurs in cases where the two independent dominant factors remain present due to an interaction between them. So the white green colour occurs either due to the absence of one or both of these factors. Now, let us consider that the factor for colour is due to two interacting complementary factors A and B and the absence of any one or both of them brings out the green colour as follows :—

Parents	Purple		AABB			
	White green		aabb			
F_1	Purple		AaBb			
F_2	Purple		White green			
	AB	—	Ab	— aB	—	ab
	9	:	3 :	3	:	1
Theoretical ratio			9 :	7		

The results in this case agree with that found by Hector (1922) in a few cases of leaf-sheath, pulvinus, auricles and outer glumes. A similar result was obtained by Parnell (1922) in ripening black character of inner glume of rice.

4. Colour character in auricle.

The colour of auricle is either white green or purple, and is noticed in the organ all throughout. The Table below shows the segregation of colour inheritance of auricle in F_2 generation of 2 families only :—

Table IV.

Segregation of colour of auricle in F_2 generation.

Cross No.	Parent varieties	No. of plants	Purple	White green	Observed ratio	Theoretical ratio
99	S. 22 White green × S. 314 Purple	125	93	32	2·9 : 1	3 : 1
192	S. 33 Purple × S. 14 White green .	140	106	34	3·1 : 1	3 : 1

Table IV shows that the colour of auricle follows the simple ratio of 3 : 1.

5. Colour character in internode.

The colour of internode is either yellow green, purple, or light brown. It is found either in long stripes in the vascular bundles or all throughout. It may also be found

in the exposed part at the apex above the leaf-sheath. The colour may be limited either to the inside or outside epidermis only or in both. The following Table shows the segregation of colour in F_2 generation of 8 families :—

TABLE V.

Segregation of colour of internode in F_2 generation.

Cross No.	Parent varieties	No. of plants	Light purple	Deep purple	Yellow green	Observed ratio	Theoretical ratio
1	M. $\frac{36}{30}$ Yellow green × As. $\frac{15}{5}$ Yellow green.	145	72	..	73	1·0 : 1	1·3 : 1
99	S. 22 Yellow green × S. 314 Deep purple.	125	..	100	25	4·0 : 1	3 : 1
			Light pink	Pink	Yellow green		
6	As. 3 Yellow green × As. $\frac{14}{3}$ Pink.	149	..	99	50	2·0 : 1	3 : 1
16	S. 127 Yellow green × S. B. 136 Pink.	91	..	65	26	2·5 : 1	„
57	S. $\frac{232}{1}$ Yellow green × S. 15 Yellow green.	127	23	..	104	1:4·5	1 : 3
			Purple	Yellow green	Light brown		
54	S. 22 Yellow green × S. 154 Purple.	158	128	20	10	12·8 : 2 : 1	12 : 3 : 1
192	S. 14 Yellow green × S. 33 Purple	140	89	36	15	5·9 : 2·4 : 1	12 : 3 : 1
188	S. 22 Yellow green × S. $\frac{158}{3}$ Light brown.	181	89	44	48	2·2 : 1 : 1·1	3 : 1 : 1·3 or 9 : 3 : 4

Table V shows that the Nos. 6, 16 and 99 follow the simple ratio of 3 : 1. No. 1 follows the ratio of 9 : 7 or 1·3 : 1, as has been explained in No. 158, Table I.

In No. 57 both the parent plants have yellow green internode. In the F_1 we get the light pink colour an entirely separate character. But unlike the segregation in No. 1, the ratio in the F_2 generation is 1 light pink : 4·5 yellow green. The explanation will not be very far to seek. Let us consider that the factor for yellow green colour in each parent is different as A and B and their respective allelomorphic absences as a and b. The colour factor here depends upon the combinations between

the conjoined characters of A, B, a and b, *i.e.*, in the absence of any of the above conjoined characters, the yellow green colour will prevail as follows :—

Parents	Yellow green	AAbb
	Yellow green	aaBB
F_1	Light pink	AaBb
F_2	AB — Ab — aB — ab	
	9 : 3 : 3 : 1	
	4 : 2 : 2 : 1	
	Light pink / Yellow green	
Theoretical ratio	4 : 12	

The individuals which are heterozygous for both the characters are the light pink coloured plants, whereas those which are heterozygous for one character only or are homozygous are all yellow green. The factors which combine here in F_1 generation from both parents are assorted independently, and their combination has no effect on the gametic formation in F_2 generation. Out of 9 individuals in AB 4 are heterozygous for 2 characters, 4 for one character and one homozygous, which is shown clearly as follows :—

AaBb	4	Light pink
AABb	2	Yellow green.
AaBB	2	Yellow green.
AABB	1	Yellow green.

This is a case similar to that obtained by Thomstone (1915) in his observation on actual natural crosses of redness of grains $\times$ whiteness of grains, where the segregation came out in the ratio of 1 : 2 : 2 : 4.

In No. 54 the internode of one of the parent plants is yellow-green and the other purple. In F_1 the purple colour is dominant in the internode. But in F_2 an intermediate colour has come out as light brown. It may be explained as follows :—

Let us consider the different factors and their absences as A, B and a, b respectively. A is for the yellow green factor and B for the purple. In the presence of A alone (absence of B) we get the green colour, and in the presence of B alone or both A and B we get the purple colour. It is the recessive characters, a and b (absence of green and pink), that bring out the intermediate or third colour factor manifesting as light brown. The reason is that the purple factor here masks the other factors and is epistatic to those for yellow-green and light brown. Where the factor for purple is lacking and the factor for the yellow-green is present, the internode is yellow

green, but where both the factors are absent the internode is light brown. Thus, the light brown internode represents the double recessive, aa bb, as shown below and consequently the total ratio of 12 : 3 : 1 is obtained. The genetic constitution in the segregation of F_2 stands as follows :—

Parents	Yellow green		AAbb	
	Purple		aaBB	
F_1	Purple		AaBb	
F_2	Purple		Yellow green	Light brown
	AB — aB	—	Ab —	ab
	9 : 3	:	3 :	1
Theoretical ratio	12	:	3 :	1

A similar instance is found in Parnell (1922) where white rice arose in F_2 from a cross, purple and red, in the ratio of 12 purple : 3 red : 1 white.

The explanation for No. 192 is the same as above, although the deviation from the theoretical ratio is (quite) marked.

No. 188 behaves in a different way. The combination of yellow green and light brown parents has brought out a third dominant factor as light purple in F_1, which is lacking in the parents. In F_2 the segregation approaches the ratio of 9 : 3 : 4 or 3 : 1 : 1·3. This is rather a complex case of factor interaction and perhaps a reversion to some original type. This is brought out by the interactions of the yellow-green and the light brown factors. The genetic constitution in F_2 may be stated as follows :—

Parents	Yellow green		AAbb	
	Light brown		aaBB	
F_1	Light purple		AaBb	
F_2	Light purple	Yellow green	Light brown	
	AB —	Ab —	aB —	ab
	9 :	3 :	3 :	1
Theoretical ratio	9 :	3 :	4	

In this case the parents differ in having a factor that produces the light purple colour in both F_1 and F_2. Accordingly, the intermediate light purple colour both in F_1 and F_2 depends on the combination of two factors, A and B, but neither of them alone is able to bring out the light purple colour. Moreover, the absence of the combination of A and B will produce either the yellow green or the light brown colour, as is shown above. This case, like the 9 : 7 ratio in No. 158, Table III, apparently shows a difference of two factors in the parents. Here the last two terms of the ordinary 9 : 3 : 3 : 1 ratio have been added together as they are not distinguiskable as two classes, thus producing a 9 : 3 : 4 ratio. The results in this case are similar to that found by Tschermack [1] (1900) in his work with eating peas (*Pisum*

[1] Bailey, L. H., and Gilbert, A. W. Plant Breeding, P. 188 (1917).

Sativum) in which he met with a ratio of 9 purple : 3 pink and white : 4 white in a cross between two types of flowers of which one is pink-and-white and the other white only.

6. Colour character in outer glume.

The colour of outer glume is either white, green or purple, and is expressed either at the apex, base or all throughout the organ.

The following Table shows the segregation of colour in F_2 generation of 7 families :—

TABLE VI.

Segregation of colour of outer glume in F_2 generation.

Cross No.	Parent varieties	No. of plants	Light purple	Purple	Deep purple	White green	Observed ratio	Theoretical ratio
6	As. 3 White green × As. $\frac{14}{3}$ Light purple.	149	96	..	..	53	1·8 : 1	1·3 : 1
16	S. 127 White green × S. B. 136 Light purple.	91	48	..	..	43	1·1 : 1	"
54	S. 22 White green × S. 154 purple.	156	..	97	..	59	1·6 : 1	"
57	S. $\frac{232}{1}$ White green × S. 15 Purple.	127	..	85	..	42	2·0 : 1	3 : 1
99	S. 22 White green × S. 314 Deep purple.	125	..	..	80	45	1·8 : 1	1·3 : 1
192	S. 33 Purple × S. 14 White green.	140	..	116	..	24	4·8 : 1	3 : 1
158	S. 152 White green × S. 14 White green.	138	61	..	..	77	1 : 1·3	1·3 : 1

Nos. 57 and 192 approximate the simple ratio of 3 : 1. In No. 158 the ratio approaches 1·3 : 1 and the explanation is the same as in No. 158, Table I. In the rest though the ratio is also 1·3 : 1, the explanation is different as has already been given in No. 192, Table III.

7. Colour character in inner glume.

The colour of inner glume is much more varied than in any other part of the plant. The colour is either green, purple, yellow, brown, black or in their different shades. It appears either in the nerves or furrows. It is also found to be in small patches or mottled in appearance.

The following Table shows the segregation of colour in F_2 of 8 families :—

TABLE VII.

Segregation of colour of inner glume in F_2 generation.

Cross No.	Parent varieties	No. of plants	Light purple	Purple	Green	Observed ratio	Theoretical ratio
6	As. 3. Green × As. $\frac{14}{3}$ Light purple	149	100	..	49	2·0 : 1	3 : 1
57	S. $\frac{232}{1}$ Green × S. 15 Purple	125	..	96	29	3·3 : 1	,,
99	S. 22 Green × S. 314 Purple	125	..	96	29	3·3 : 1	,,
158	S. 152 Green × S. 14 Green	138	57	..	81	1 : 1·4	1·3 : 1
			Yellow		Brown		
54	S. 22 Yellow (mature) × S. 154 Brown (mature).	156	110	..	46	2·4 : 1	3 : 1
			Green		Light brown		
188	S. 22 Green × S. $\frac{158}{3}$ Light brown.	181	133	..	48	2·8 : 1	3 : 1
			Yellow	Inter-mediate	Deep brown		
94	S. 135 Deep brown (mature) × S. 156 Yellow (mature).	164	94	61	9	10·4 : 6·8 : 1	9 : 6 : 1
			Black	Inter-mediate	Yellow		
192	S. 33 Black (mature) × S. 14 Yellow (mature)	140	76	56	8	9·5 : 7·0 : 1	9 : 6 : 1

Table VII shows that Nos. 6, 57, 99, 54 and 188 follow the simple ratio of 3 : 1 while No. 158 behaves like No. 158 in Table I. In No. 94 the segregation in F_2 has occurred in a quite different way. This is also a deviation from the ordinary 9 : 3 : 6 : 1 ratio, where the two middle terms have been added together to bring it to a 9 : 6 : 1 ratio.

Now, let us consider the factors for colour as A and B and their allelomorphic absences as a and b. The yellow colour appears by the combination of the double dominants, A and B, and the deep brown by the corresponding double recessives, a and b. The genetic constitution may be stated as follows :—

Parents	{ Yellow . . .	AABB						
	{ Deep brown . .	aabb						
F_1	Yellow . . .	AaBb						
F_2	Yellow . .	Intermediate			Deep brown			
	AB	—	Ab	—	aB	—	ab	
	9	:	3	:	3	:	1	
Theoretical ratio	9	:	6			:	1	

The presence of both the factors A and B produces the yellow and their absence the deep brown colour. The intermediate colour is brought out in the presence of either A or B. The intermediates here are a mixture of yellow and deep brown which are easily separable. Consequently, the ratio of 9 : 6 : 1 shows distinctly three visible classes which are genetically different. In fact, there are 94 yellow : 61 yellow deep brown : 9 deep brown.

Of the 94 yellow-seeded plants 10 came out with yellow grains in the F_3 generation and the rest splitted again, of which some were either yellow or deep brown and the others intermediate as in F_2. Similarly, from the 61 plants with intermediate coloured grains 14 were found to be pure, the rest segregating as in F_2 generation. The 9 plants with the recessive deep brown grains bred true.

No. 192 behaved similar to No. 94.

8. Colour character in tip.

The colour of tip is either white green, purple or light brown and is manifested on the point of the tips of the two inner glumes. Exception was found in a few cases of *Aus* and rarely in *Sail*, where one tip was slightly coloured and the other colourless. The following Table will show the segregation of colour in F_2 generation of 9 families :—

TABLE VIII.

Segregation of colour of tip in F_2 generation.

Cross No.	Parent varieties	No. of plants	Light purple	Purple	Deep purple	White green	Observed ratio	Theoretical ratio
1	M. $\frac{36}{30}$ White green × As. $\frac{15}{5}$ Light purple.	146	111	..	..	35	3·2 : 1	3 : 1
6	As. 3 White green × As. $\frac{14}{3}$ Purple.	149	..	120	..	29	4·1 : 1	,,
16	S. 127 White green × S. B. 136 Deep purple.	91	..	..	65	26	2·5 : 1	,,
54	S. 22 White green × S. 154 Purple.	156	..	126	..	30	4·2 : 1	,,
57	S. $\frac{232}{1}$ White green × S. 15 Purple.	124	..	105	..	19	5·5 : 1	,,
99	S. 22 White green × S. 314 Deep purple.	125	..	..	100	25	4·0 : 1	,,
188	S. 22 White green × S. $\frac{158}{3}$ Light purple.	181	140	..	..	41	3·4 : 1	,,
192	S. 33 Purple × S. 14 White green.	140	..	117	..	23	5·1 : 1	,,
158	S. 152 White green × S. 14 White green.	139	79	..	..	60	1·3 : 1	1·3 : 1

Almost all the crosses follow the simple ratio of 3 : 1, more or less, except No. 158 where the ratio is equivalent to 1·3 : 1, as has been explained before in No. 158, Table I.

9. Colour character in stigma.

The stigma of rice flower is bifurcated and plumose and is either white or purple. The colour of this organ is in the plumose structure which may be expressed partly or completely. Sometimes only a few bristles in the plumose stigma are found to be coloured.

The following Table shows the segregation of colour in F_2 generation of 9 families :—

Table IX.

Segregation of colour of stigma in F_2 generation.

Cross No.	Parent varieties	No. of plants	Deep purple	White	Purple	Observed ratio	Theoretical ratio
1	M. $\frac{36}{30}$ White × As. $\frac{15}{5}$ Deep purple.	146	112	34	..	3·3 : 1	3 : 1
6	As. 3 White × As. $\frac{14}{3}$ Deep purple.	149	120	29	..	4·1 : 1	,,
188	S. 22 White × S. $\frac{158}{3}$ Deep purple.	181	140	41	..	3·4 : 1	,,
16	S. 127 White × S. B. 136 White	91	53	38	..	1·4 : 1	1·3 : 1
54	S. 22 White × S. 154 White .	156	78	78	..	1·0 : 1	,,
99	S. 22 White × S. 314 White .	125	67	58	..	1·2 : 1	,,
158	S. 152 White × S. 14 White .	139	64	75	..	1 : 1·2	,,
57	S. $\frac{232}{1}$ White × S. 15 White .	125	86	39	..	2·2 : 1	,,
192	S. 33 White × S. 14 White .	140	..	132	8	16·5 : 1	15 : 1

From the Table IX it is noticed that with one exception all the crosses follow either the ratio of 3 : 1 or 1· 3 : 1. No. 192 behaves in an unusual way. The peculiarity of this cross lies in the fact that both the parental characters are white and the resulting F_1 is also white (Dominant), but F_2 generation brings out a coloured progeny though in minority, the genetic constitution of which may be stated as follows :—

Parents	{ White . . . { White . . .	AAbb aaBB
F_1	White . . .	AaBb
F_2	$\overbrace{\text{White . . .}}$	Purple
	AB — Ab — aB —	ab
	9 : 3 : 3 :	1
Theoretical ratio	15 :	1

This is a rare example of double white dominant and double purple recessive factors. It may be assumed that the presence of either of the single white dominant factors or the combination of both together develops the white stigma and that being the case with 15 of the F_2 types, they have necessarily come out as white. Only one out of sixteen has neither of the white factors and this is the plant with double recessive purple factors.

The purple colour appears in the case where the two separate white factors (A and B) of both the parents are absent. The presence of either of the parental white factors will bring out a white progeny and so we get the ratio as 15 white : 1 coloured. It may be argued that a purple factor acting independently produces such an unusual aberrant type. But in F_3 generation the 8 plants with coloured stigma bred true to type so far as the colour of stigma is concerned and hence their chance of being accidentally crossed does not seem to be so evident. Hector (1922) found a similar ratio in several crosses of coloured with non-coloured plants, where this type of segregation occur; very frequently with the coloured factor being dominant.

10. Colour character in kernel.

The colour of kernel is either white or red, but an exception was noticed in one type, S. 314, where the kernel is deep purple or black. In some of the fine Joha varieties the kernel is white with a green tinge. The segregation of colour in the kernel of rice in F_2 generation is shown below in 6 families :—

Table X.

Segregation of colour of kernel in F_2 generation.

Cross No.	Parent varieties	No. of plants	Red	White	Amber	Observed ratio	Theoretical ratio
1	M. $\frac{36}{30}$ Red × As. $\frac{15}{5}$ White .	86	64	22	..	2·9 : 1	3 : 1
6	As. 3 White × As. $\frac{14}{3}$ Amber .	149	..	117	32	3·7 : 1	,,
117	S. 23 White × S. B. 28 Red .	176	127	49	..	2·6 : 1	,,
16	S. 127 Red × S. B. 136 White.	91	57	34	..	1·7 : 1	1·3 : 1
217	S. 22 White × Wild paddy Red	56	48	8	..	6·0 : 1	3 : 1
			Black	Inter-mediate	White		
99	S. 22 White × S. 314 Black .	125 F_1 Inter-mediate	32	67	26	1·2 : 2·6 : 1	1 : 2 : 1

Nos. 1, 6, 117 and 217 follow the simple ratio of 3 : 1, although the last one deviates to a great extent from the theoretical ratio. In F_3 generation, the 8 plants were found to breed true, whereas out of 48 red plants 21 came out to be pure and the rest splitted again. This evidently proves that the case is an aberrant type of the simple ratio of 3 : 1.

No. 16 has behaved exactly as in No. 192, Table II, where it is discussed fully. The ratio 1 : 2 : 1 in No. 99 shows distinctly three visible classes which are genetically different. There are 32 black : 67 black white : 26 white, each of which is easily separable. This agrees with the results obtained by Parnell (1917) in a cross between green and dark gold as well as in golden colouring of inner glumes (1922). Hector (1922) also met with a similar ratio where the segregation was found to be 1 red : 2 pale red : 1 white.

Summary.

1. The inheritance of colour in rice is very complicated. The colour complexes are not fixed in a particular part of any organ.

2. The factor that produces the colour exists in some part of the parent plants, either visible or invisible, which effects the expression of colour when suitable factor combinations occur by cross-fertilization.

3. The factors for purple, pink, brown, yellow, red, black, white and green are independent of each other and so is the actual shading of each one of them as light or deep colour.

4. Generally, coloured factors are dominant over non-coloured ones. Purple is dominant over green or white, red over white, green or yellow over brown, and black over green or yellow. Exception is found in one case of pulvinus character where purple is dominant in F_1 as light purple, and also another in kernel where white is dominant over amber.

5. In majority of cases where coloured and non-coloured factors were crossed, simple Mendelian ratio of 3 : 1 prevailed. Exceptions were met with a number of cases where the ratios were 9 : 7, 12 : 3 : 1, 9 : 3 : 4, 9 : 6 : 1 and 1 : 2 : 1.

6. In a few crosses between non-coloured plants the segregation occurred in the ratio of 9 coloured : 7 non-coloured except two cases, where the ratios were 15 : 1 and 1 : 3 respectively.

7. The existence of an original third colour factor was found in all cases, where intermediates arose in F_2, which were distinctly crosses between coloured and non-coloured plants.

Literature cited.

1. Hector, G. P. Notes on pollination and cross-fertilizaton in the common rice plant. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. VI, No. 1 (1913).
2. Hector, G. P. Observations on the inheritance of anthocyan pigment in paddy varieties. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. VIII, No. 2 (1916).

3. Hector, G. P., 1922. Correlation of colour characters in rice. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XI, No. 7 (1922).
4. Parnell, F. R., Rangaswami Ayyangar, G. N., and Ramiah, K. The inheritance of characters in rice. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. IX, No. 2 (1917).
5. Parnell *et al.* The inheritance of characters in rice, II. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XI, No. 8 (1922).
6. Bateson, W., Saunders, E. R., Punnett, R. C., Hurst, C. C. *et al.* Sweet pea. *Roy. Soc. Evol., Rept.* II (1905).
7. Thompstone, E. Some observations on Upper Burma paddy. *Agricultural Journal of India*, Vol. X, Part I.

ASTERINA SPP. FROM INDIA.

DETERMINED BY

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(Received for publication on 9th June 1927.)

Asterina holarrhenæ, n. sp.

The fungus occurs on the upper surface of the leaves in distinct patches, 2-3 mm. in diameter. Perithecia numerous, round, radiate, carbonaceous; margin fimbriate and light brown, ostiolate, 115-214 μ in diameter. Mycelium grey-brown, straight, 4 μ thick. Hyphopodia sessile, alternate, 3-lobed, 4×10 μ, one-celled. Asci spherical, 34-44 μ in diameter. Spores 2-celled, 12×26-30 μ, brown, the free end of each cell rounded, smooth. The fungus is near *Asterina sphaerotheca*, but differs from it in the size and shape of the perithecia and asci.

On *Holarrhena antidysenterica* Wall. Syndai, Khasi and Jaintia Hills, Assam, Jan. 1915. Leg. L. S. Subramaniam. Herb. Crypt. Ind. Orient. No. 1963.

Asterinella Winteriana (Pezschke) Th.

Fungus epiphyllous. It agrees with the description for *A. Winteriana* Th. *Syll. Fung.* XI, 1255.

Scattered on the lower surface of the leaf are numerous small black spots of another *Asterina*. When examined, the fungus proved to be immature. The general structure of the perithecia and absence of external mycelium shows relationship to Microthyrium and Seynesia. The perithecial covering is striking. It is light straw color with irregularly scattered dark brown sharp pointed cells.

On *Castanopsis* sp. Pachanadi, Mangalore. Apr. 16, 1913. Leg. L. S. Subramaniam. Herb. Crypt. Ind. Orient. No. 1965.

Asterina cansjeræ, n. sp.

The fungus occurs on both surfaces of the leaves in small spots, 2-3 mm. in diameter. Perithecia numerous, carbonaceous, margin distinctly radiate and fimbriate, ostiolate, opening by radiating fissures, $160\text{-}200 \times 120\text{-}144$ μ. Mycelium light brown, straight, 4 μ thick. Hyphopodia alternate, of two kinds—short sessile, lobed, 4×4 μ, and cylindrical 10×6 μ. Numerous brown conidia, pear shaped, 12×22 μ. Asci ovate, $28\text{-}32 \times 36\text{-}44$ μ. Spores dark brown, 2-celled, margin rough 8×18-22 μ.

On *Cansjera Rheedii* Gmel. Dharwar, Bombay, Oct. 1918. Leg. L. J. Sedgwick. Herb. Crypt. Ind. Orient. No. 1966.

Asterina nothopegiæ, n. sp.

Fungus occurs on both sides of the leaves. Perithecia are clustered, round, black, ostiolate, margin fimbriate, 132-181 μ in diameter. Mycelium chocolate brown, 10 μ, thick. Hyphopodia alternate 2-celled, cylindrical to slightly lobed, $12 \times 28{\cdot}32$ μ. Asci globose to oval, $20\text{-}33 \times 25\text{-}42$ μ. Spores dark brown, 2-celled $8\text{-}10 \times 20\text{-}28$ μ.

On *Nothopegia Colebrookiana* Bl. Talguppi, Mysore, Oct. 29, 1911. Leg. G. S. Kulkarni. Herb. Crypt. Ind. Orient. No. 1970.

Asterina memecyloniæ, n. sp.

Fungus forms dark spots 3=4 mm. in diameter on the leaves. Perithecia round, 132 μ in diameter. Mycelium brown, 6 μ thick. Hyphopodia sessile, knob shaped, 8×12 μ. Asci ovate, 36×64 μ. Spores 2-celled, dark brown, 14×36 μ.

On *Memecylon edule*. Karwar, Bombay, Oct. 1919. Leg. L. J. Sedgwick. Herb. Crypt. Ind. Orient. No. 1972.

There is also another Microthyriaceous fungus, but no asci or spores could be found, so no determination could be made.

Asterina pluriporus, n. sp.

Fungus forms large irregular black spots on the lower surface of the leaves, 2-10 mm. in diameter. Perithecia round, carbonaceous, numerous ostioles, margin light brown, radiate, fimbriate, 264-848 μ in diameter, Mycelium light brown, wavy, 6 μ thick.

Hyphopodia crook-shaped, one-celled $12\text{-}14 \times 24\text{-}36$ μ. Asci ovate to globose, $80\text{-}84 \times 84\text{-}104$ μ. Spores brown, 2-celled, $24\text{-} \times 40\text{-}42$ μ.

On *Shorea Talura* Roxb. Siddapur, N. Kanara, Oct. 1919. Leg. L. J. Sedgwick. Herb. Crypt. Ind. Orient. No. 1975.

Morenoella shoreae, n. sp.

On the upper surface of the leaves forming small irregular spots. Perithecia linear, carbonaceous, with a longitudinal fissure, $330\text{-}346 \times 247\text{-}544$ μ. Margin irregular, fimbriate and distinctly radiate, light brown. Mycelium brown, nodulate, 6 μ thick, straight. Asci oval to globose, aparaphysate, $40 \times 48\text{-}52$ μ. Spores brown 2-celled, 4 spores to an ascus, $20 \times 36\text{-}40$ μ.

On *Shorea Talura*. Siddapur, N. Kanara, Oct. 1919. Leg. L. J. Sedgwick. Herb. Crypt. Ind. Orient. No. 1975.

Asterinella intensa (Che. and Mass.) Th.

Broteria, 10 : 101-123, 1912.

Fungus is very like *Asterinella intensa* as described, except that the perithecia are slightly smaller. Asci and spores correspond to the measurements given.

On *Elaeodendron glaucum* Pers. Madras. Herb. Crypt. Ind. Orient. No. 1976.

MELIOLA SPP. FROM INDIA AND ONE FROM MALAY.

DETERMINED BY

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(Received for publication on 9th June 1927.)

Meliola theacearum, n. sp.

Colonies amphigenous, mainly epiphyllous, 1-3 mm. in diameter or coalescing to cover the leaf, dense to crustose in old regions, loose at edge of colony. Mycelium nearly straight, black, 7-11 μ thick. Spot none. Capitate hyphopodia alternate, about 18 μ apart. Stalk cell short, 3-4 μ ; head cell oblong, 14×10 μ. Mucronate hyphopodia ampulliform, abundant. Perithecial setae none. Mycelial setae very few, simple, obtuse or short toothed, 390-800 μ long. Perithecia globose, rough, on radiate disks, small, 125 μ. Asci 2-4 spored, evanescent. Spores 4-septate, $42\text{-}46 \times 18\text{-}22$ μ, middle cell larger.

Group number 311-31. 4323. Herb. Crypt. Ind. Orient. No. 1982. On Theaceae, *Schima*.

Malay : Penang, Govt. Hill, July 1918. Leg. E. J. Butler. Plate I, figures 1 to 4.

This is of special interest as the only true *Meliola* recorded upon any member of the Theaceæ. In a general key, it would fall near *M. litseae* from which it is separated by the nature of the setal branches.

Meliola eugeniicola, n. sp.

Colonies amphigenous, thin, circular, 1-5 mm. in diameter. Mycelium straight, thick, 7 μ, dark, branching often nearly at right angles. Spot none. Capitate hyphopodia opposite, antrorse, close, 18 μ. Stalk cell short, 3-4 μ ; head cell cylindrical or slightly irregular, $14\text{-}15 \times 7\text{-}8$ μ. Mucronate hyphopodia ampulliform. Perithecial setae none. Mycelial setae long, 460-1100 μ, simple, acute, straight or gracefully flexuose. Perithecia dimidiate when young, globose when mature, smooth, 140 μ in diameter, from alveolar disks. Asci evanescent. Spores 4-septate, 43×18 μ.

Group number 3112×4224. Herb. Crypt. Ind. Orient No. 1989. On Myrtaceæ. *Eugenia eucalyptoides* F. Muell.

India : Pachanadi, Mangalore, April 16, 1913. Leg. L. S. Subramaniam.

Plate II, figures 9 to 11.

Though some twenty-five species of the Meliolinæ have been described on the Myrtaceæ, this shows superficial resemblance with only two, *viz.*, *M. amomicola* from which it differs markedly in colony and mycelial characters and in the fact

that the hyphopodia are strictly opposite; and *M. horrida Rehm* (not Ell. & Ev.) from which it differs in its setae and colony.

In a general key, it would fall with these *Meliolas* of formula 3112 with acute setae. From all of these it differs in length of setae.

Meliola holigarnae, n. sp.

Colonies hypophyllous, sub-circular, 1-3 cm. in diameter, sooty black, velvety. Mycelium thin, pale non-adherent. Spot none. Capitate hyphopodia alternate, not abundant, very irregular and irregularly spaced. Stalk cell short, 11 to 22-30 μ long; head cell very irregular, ovate, clavate or lobed, 25 × 14 μ. Mucronate hyphopodia ampulliform, few. Perithecial setae none. Mycelial setae simple, obtuse, dark, very numerous, crooked, 540-620 μ. Perithecia globose, rough, 114-266 μ. Asci mostly 2-spored, ovate, 50-88 × 22-44 μ. Spores elliptical, 4-septate, middle cell much larger than the others, 60-69 × 24-30 μ.

Group number 3111—6333. Herb. Crypt. Ind. Orient No. 1981 and 1986*a*.

On Anacardiaceæ, *Holigarna Grahamii*.

India: Anmod, N. Kanara, Dec. 25, 1917, No. 1981. Leg. L. J. Sedgwick. Ekambi, N. Karnara, Oct. 1919, No. 1986*a*. Leg. L. J. Sedgwick. Plate I, figures 5 to 8.

No species resembling this has been noted on the Anacardiaceæ or indeed on any other host. The abundant non-adhering mycelium with very irregularly spaced hyphopodia which are also irregular in shape as well as spores of great size and characteristic shape are distinctive. The aspect of the fungus throughout is rather that of a *Meliolina* than of a *Meliola* and the scarcity of hyphopodia emphasizes this relationship. It constitutes a very interesting transition form between these genera.

Meliola pterospermi, n. sp.

Colonies epiphyllous, black, circular, 1-3 mm. in diameter, often confluent and largely covering the leaf. Mycelium dark, crooked, closely tangled, but hardly crustose, 7-8 μ thick. Capitate hyphopodia alternate, numerous. Stalk cell short, 3-4 μ; head cell clavate, usually irregular to lobed, sometimes crenate, 18 × 14 μ. Mucronate hyphopodia ampulliform. Perithecial setae none. Mycelial setae simple, 200-425 μ, obtuse, dark, lighter at tip, often curved, septate. Perithecia globose, rough, 175-250 μ in diameter, arising from radiate disks. Asci 2-4-spored, evanescent, 50-80 × 17-35 μ. Spores 4-septate, 35-50 × 15-22 μ, middle cells generally swollen.

Group number 3111. 4332. Herb. Crypt. Ind. Orient. No. 1987.

On Sterculiaceæ, *Pterospermum* sp.

India: Bassein, Burma, Nov. 30, 1912. Leg. E. J. Butler.

Plate II, figures 12 to 14 and Plate III.

No true *Meliola* has heretofore been reported upon any of the Sterculiaceæ. In general classification this species is near *M. tamarindi.*

Meliola indica, Sydow var, *caryae,* n. var.

On Lecythidaceæ, *Careya arborea* Roxb.

India: Gairsoppa Falls, N. Kanara, Oct. 1919. Herb. Crypt. Ind. Orient. No. 1985. Leg. L. J. Sedgwick.

This differs from the Philippine type in its longer setae (to 650 μ) and its slightly elongate hyphopodia and crooked mycelium.

Meliola elmeri Sydow. *Leaf. Phil. Bot.* 5 : 1537, 1912.

On Pittosporiaceæ, *Pittosporum dasycaulon* Miq.
India: Ghat Forests, N. Kanara, Oct. 1919. Leg. L. J. Sedgwick.
Herb. Crypt. Ind. Orient. No. 1983.

Meliola sakawensis. Hennings, Hedw 43 ; 141. 1904.

On Verbenaceæ, *Vitex leucoxylon* Linn.
India: N. Kanara, Bombay, Oct. 1919. Leg. L. J. Sedgwick.
Herb. Crypt. Ind. Orient. No. 1984.

Meliola crescentiae Stevens. in lit.

On Bignoniaceae, *Heterophragma* Roxburghii. D. C.
India: Dharwar, Bombay, Dec. 1918. Leg. L. J. Sedgwick.
Herb. Crypt. Ind. Orient. No. 1993.

Meliola simillime E. and E. Ann. Rept., Mo. Bot. Gard. 9 : 118. 1898.

Syn. Meliola *wrightiae* Yates, *Phil. Jour. Sc.* 13 : 371. 1918.
On Apocynaceæ, *Holarrhena antidysenterica* Wall.
India: Dacca, March 12, 1913. Leg. A. L. Som.
Herb. Crypt. Ind. Orient. No. 1988.

Meliola arundinis, Pat. *Jour. d. Bot.* 11 : 348, 1897.

On Gramineae, *Phragmites Karka* Trin.
India: Ballabari, Kamrup, Assam, Feb. 27, 1912. Leg. M. Taslim.
Herb. Crypt. Ind. Orient. No. 1991.
Herb. Crypt. Ind. Orient. No. 1990. Puttimari, Feb. 25, 1912. Leg. M. Taslim.

These specimens are of somewhat unusual interest in that the setae are sometimes simple.

Meliolineae ind.

The following specimens are worthy of record as showing geographic and host distribution though the species cannot be determined either owing to suppression of characters by parasites or to scantiness of material.

Herb. Crypt. Ind. Orient No. 1992.

On Pandanaceæ, *Pandanus.*

India : Salebile, Mysore, 10th Sep. 1903. Leg. E. J. Butler.

Spores 4-septate, hyphopodia alternate. All colonies very heavily parasitized. It is especially desirable that determinable specimens be collected since no one of the Meliolineæ has been reported on this host family.

Herb. Crypt. Ind. Orient. No. 1986*b*.

On Myrtaceæ, *Eugenia latifolia.*

India ; Pachanadi, Mangalore, Apr. 16, 1913. Leg. L. S. Subramaniam.

Spores 4-septate, 40-46 × 15-18 μ, hypopodia alternate.

Herb. Crypt. Ind. Orient. No. 1995*a*.

On Rutaceæ, *Citrus* sp.

India : Calicut, Malabar, Sept. 29, 1904. Leg. E. J. Butler.

Very heavily parasitized.

Herb. Crypt. Ind. Orient. No. 1995*b*.

On Rutaceæ, *Citrus acida*. Roxb.

India : Wahjain, Assam, May 17, 1905. Leg. Inayat Khan.

Very heavily parasitized.

It is of interest to note that these heavily parasitized specimens from India bear identically the same species of parasites, chiefly of the genera *Speggazzinia*, *Helminthosporium* and *Arthrobotrium* that are found in Africa, Hawaii and the Americas.

Herb. Crypt. Ind. Orient. No. 1994.

On Rubiaceæ, *Ixora parviflora.*

India : Bilikeri, Mysore, Sept. 1920, 1903. Leg. Inayat Khan.

This is possibly either *Irene uncaria* or *I. cryptocarpa*, but it is too heavily parasitized to determine certainly.

Specimens of *Asterina* and of *Meliola* from the herbarium of the Agricultural Research Institute, Pusa, were sent to the Imperial Bureau of Mycology, London. for the purpose of having them named. The material from which the specimens were named is deposited in the herbarium of the Imperial Bureau of Mycology, London, while the bulk material is in the herbarium of the Agricultural Research Institute, Pusa.

W. McRae,
Imperial Mycologist.

EXPLANATION OF PLATES.

Plate I.

Meliola theacearum, n. sp.

Fig. 1. Mycelium showing habit.
Fig. 2. Mycelium showing mucronate hyphopodia.
Fig. 3. Mycelium showing capitate hyphopodia.
Fig. 4. Setae showing tips.

Meliola holigarnae, n. sp.

Fig. 5. Mycelium showing habit with a perithecium.
Fig. 6. Mycelium showing mucronate hyphopodia.
Fig. 7. Mycelium showing capitate hyphopodia.
Fig. 8. Spores.

Plate II.

Meliola eugeniicola, n. sp.

Fig. 9. Mycelium showing habit.
Fig. 10. Mycelium showing mucronate hyphopodia.
Fig. 11. Mycelium showing capitate hyphopodia.

Meliola pterospermi, n. sp.

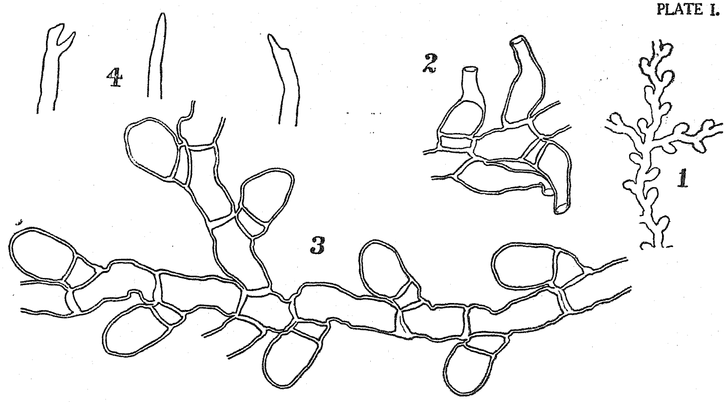
Fig. 12. Mycelium showing habit.
Fig. 13. Mycelium showing mucronate hyphopodia.
Fig. 14. Mycelium showing capitate hyphopodia.

Plate III.

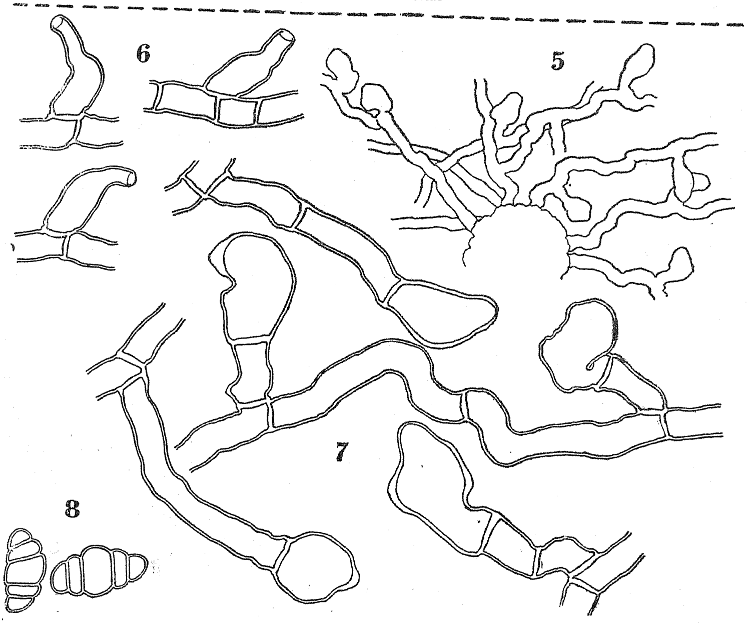
Meliola pterospermi, n. sp.

Photograph showing general habit.

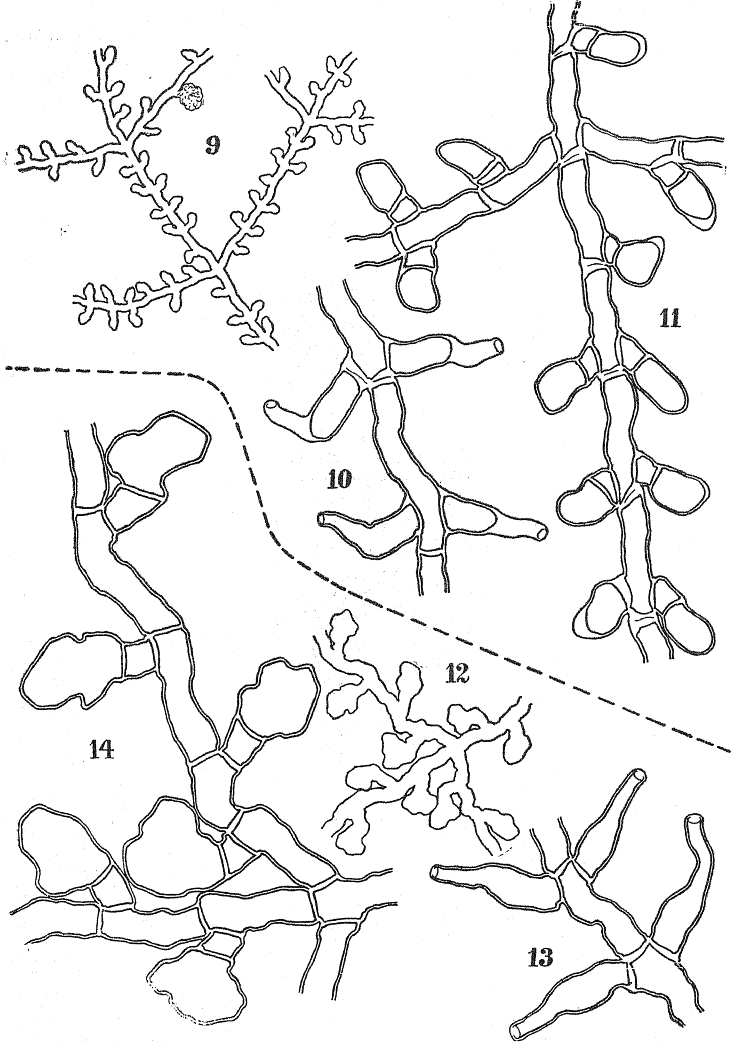
MGIPC—M—IV-2-50—10-2-28—650.



Meliola theacearum Stevens.



Meliola holigarnae Stevens.



Meliola pterospermi Stevens.

PLATE III.

Meliola pterospermi Stevens.

PREFACE.

The rice breeding work in Sind was started in the harvest season of 1921 by Mr. T. F. Main, B.Sc., O.B.E., then Deputy Director of Agriculture in Sind, when a large number of single earheads in 10 varieties of Sind rice had been selected. These were handed over to me for study in February 1922 when the work was placed in my charge. More material was collected by me in the following season. By the end of 1923 I prepared a note embodying my work regarding classification and description of Sind rices, their morphological and agronomic characters, problems of fertilization and sterility and selection and testing of strains in the three principal local varieties. This note was then submitted by me for publication as a memoir but I was advised by the Director of Agriculture, Bombay, to postpone the publication till I had obtained more comprehensive data on the subject of selection and breeding of improved strains which after all was the ultimate object of the study.

At this stage Mr. Durgadutt joined me as Graduate Assistant for rice breeding and since then, from 1924, we concentrated our attention on further work of selection and breeding in Sind rice and also on acclimitization of foreign rices. The data then obtained were incorporated by me in my original note. For the assistance rendered by Mr. Durgadutt I am thankful to him and have associated his name as joint author.

I also acknowledge my indebtedness to Mr. T. F. Main, B.Sc., O.B.E., for his encouragement during the early part of this work and to Dr. Harold H. Mann, D.Sc., for his valuable help in presenting this memoir in its present form.

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CONTENTS

PLATES

STUDIES ON RICE IN SIND, PART I.

BY

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(Received for publication on 25th July 1927.)

I. Introduction.

By far the most extensively grown crop in Sind is rice, though this province has, in no part, where rice is cultivated, a greater average rainfall than ten inches per annum. As a result, it is exclusively an irrigated crop, depending at present on the flow in inundation canals from the river Indus, in which water is avaliable, as a rule, only from June to September. In spite of this limitation, the total area under the crop is about one and a quarter million acres, divided between two tracts of very different character, widely separated from one another. Fig. I shows the distribution and the relative intensity of rice cultivation in these tracts in the last year for which we have records, and the following table indicates the areas in the different Districts.

District	Area in 1925-26 Acres
Larkana	412,274
Sukkur	78,933
Upper Sind Frontier	111,285
Nawabshah	36,443
Hyderabad	261,717
Thar and Parkar	61,203
Karachi	240,907

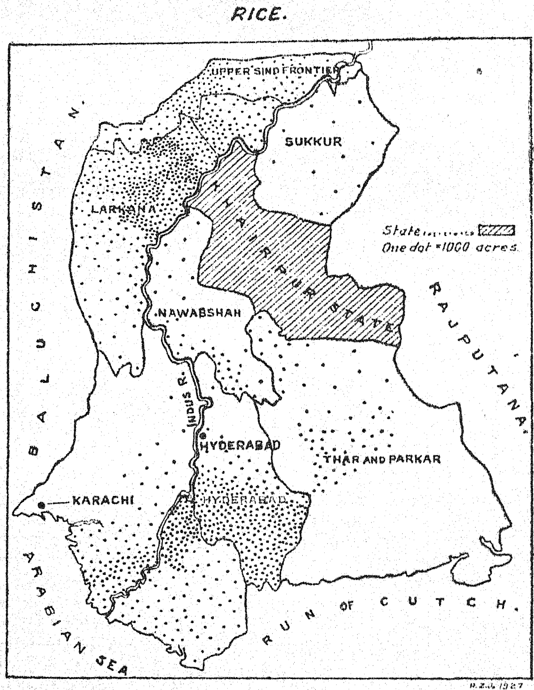


FIG. 1. Distribution of rice crop in Sind.

The Upper Sind rice tract is centred on the Larkana District, but extends into the Sukkur and Upper Sind Frontier Districts. These are among the hottest areas in India, but are supplied with water by flow irrigation in the inundation season. The land is alluvial and is usually well drained naturally. The conditions are very suitable for rice cultivation, yields up to 3,200 lb. of grain per acre are not uncommon, and high class rice is grown. Almost all the crop is transplanted from nursery beds.

The Lower Sind rice is grown in an area which is, to a great extent, actually in the delta of the Indus, with an extension to the east into the Nara valley. It com-

prises the lower parts of the Hyderabad and Karachi Districts (known as the '*Lar*') and a portion of the Thar and Parkar District. The area differs from Upper Sind in a considerably cooler climate during the rice growing season, both by day and night, and far more moist atmospheric conditions. The water is much less under control than Upper Sind, and hence the rices have to be and are adapted for the deep water conditions which prevail in a large part of the tract. The crop in the Nara valley and in a large part of the *Lar* is broadcasted; in the remainder of the *Lar* it is transplanted as in Upper Sind.

The varieties of rice grown are, as would be judged, very various and widely differing in character, and the object of the present paper is to present, on the one hand, a classification and short description of the special characters of the various types which have been found, and on the other, to describe the investigations which have been made on three of the more important varieties grown in Upper Sind, and on their improvement. These three varieties are *Kangni*, a type which occupies seventy-five per cent. of the area under the crop in Upper Sind, and *Jajai* and *Prong* two commonly grown so called *sugdasi* or flavoured varieties.

II. Classification of varieties of rice in Sind.

Species of rice in Sind. Though almost the whole of the rice found in Sind, cultivated or wild, belongs to the species *Oryza sativa*, yet there occurs in the delta—in the Shah Bunder taluka and the Keti Bunder mahal of the Karachi District—a wild species which has been named *Oryza coarctata* or *Oryza triticoides*. Its occurrence is limited to the swamps of the Indus delta where salt water mingles with fresh water. There the plant is known as *suan* grass, and the grain as *nanoi*. The mature grain sheds completely, and is gathered by the local inhabitants for food, while the straw is eaten by cattle, especially by buffaloes. The grain resembles wheat, and is stated by Watt to be carried all over India by Hindus for use on certain ceremonial occasions.

No further reference need be made to this special wild form of *Oryza*. There are, however, very many varieties of *Oryza sativa*, or rice proper, both wild and cultivated. The wild forms often appear as weeds in cultivated rice, and are frequent sources of contamination. Most of the wild types are characterised by the presence of long, very rough and stout awns, which are usually red or even scarlet, in colour, and all have the character of shedding most or all of their grain.

The cultivated varieties of rice in Sind are many, and thirty-five of these have been classified in the following table. In this table, the first distinction has been made between bearded and beardless rices, and then the following characters[1] have been used in succession in separating the various types :—

(*a*) Colour of leaf sheath—green or red.

(*b*) Colour of grain—white or red.

[1] These characters, as applied to Sind rices, are discussed fully on pages 121—138.

(c) Character of grain—long, fine or coarse.
(d) Colour of inner glumes, white, yellow, red, or black.
(e) Colour or lack of colour of the *tip* of inner glumes.
(f) Colour or lack of colour of the outer glumes.

Using the characters named, in this order, it has been possible to bring all the known varieties of rice in Sind into one comprehensive scheme.

Beardless varieties.

I. Rice with green leaf sheath.
  1. Grain white.
    B. Grain fine.
      (a) Inner glumes white.
        (i) apiculus and outer glumes colourless.
          Variety I. *Parsad.*
          „ II. *Barsati.*
      (b) Inner glumes yellow.
        (i) apiculus and outer glumes colourless.
          Variety III. *Jirashahi.*
        (ii) apiculus and outer glumes coloured.
          Variety IV. *Jajai.*
          „ V. *Unnamed new Type A* (*Sugdasi*).
          „ VI. *Chajrai.*
          „ VII. *Unnamed new Type X.*
      (c) Inner glumes red.
        (i) apiculus and outer glumes colourless.
          Variety VIII. *Red Kangro.*
          „ IX. *Bidri.*
          „ X. *Sathri.*
        (ii) apiculus and outer glumes coloured.
          Variety XI. *Ratrya.*
    C. Grain coarse.
      (a) Inner glumes white.
        (i) apiculus and outer glumes colourless.
          Variety XII. *Ganjro.*
      (d) Inner glumes black.
        (i) apiculus and outer glumes coloured.
          Variety XIII. *Pista* or *Kariaro.*

II. Rice with red leaf sheath.
  1. Grain white.
    B. Grain fine.
      (*a*) Inner glumes white.
        (i) apiculus and outer glumes colourless.
          Variety XIV. *Kangni.*
          ,, XV. *Sathrya.*
    C. Grain coarse.
      (*a*) Inner glumes white.
        (i) apiculus and outer glumes colourless.
          Variety XVI. *Kunjro.*
          ,, XVII. *Torh.*
  2. Grain red.
    B. Grain fine.
      (*a*) Inner glumes white.
        (iii) apiculus coloured and outer glumes colourless.
          Variety XVIII. *Unnamed New Type G.*
    C. Grain coarse.
      (*a*) Inner glumes white.
        (i) apiculus and outer glumes colourless.
          Variety XIX. *Sindhi kambroo.*
        (iv) apiculus coloured and outer glumes colourless.
          Variety XX. *Unnamed New Type Y.*
          ,, XXI. *Ganja.*
          ,, XXII. *Lari.*
          ,, XXIII. *Motya.*

BEARDED VARIETIES.

I. Rice with green leaf sheath.
  1. Grain white.
    A. Grain long.
      (*b*) Inner glumes yellow.
        (i) apiculus and outer glumes colourless.
          Variety XXIV. *Sighro.*
      (*c*) Inner glumes red.
        (i) apiculus and outer glumes coloured.
          Variety XXV. *Sonahiri.*
          ,, XXVI. *Sada Gulab.*

B. Grain fine.

(*a*) Inner glumes white.

(i) apiculus and outer glumes colourless.

Variety XXVII. *Unnamed New Type B.*

(*b*) Inner glumes yellow.

(ii) apiculus and outer glumes coloured.

Variety XXVIII. *Unnamed New Type C.*

„ XXIX. *Prong.*

„ XXX. *Bengalo.*

C. Grain coarse.

(*a*) Inner glumes white.

(iii) apiculus colourless and outer glumes coloured.

Variety XXXI. *Motiaro.*

II. Rice with red leaf sheath.

2. Grain red.

B. Grain fine.

(*a*) Inner glumes white.

(ii) apiculus and outer glumes coloured.

Variety XXXII. *Unnamed New Type Za.*

C. Grain coarse.

(*a*) Inner glumes white.

(i) apiculus and outer glumes colourless.

Variety XXXIII. *Unnamed New Type, D.*

(iv) apiculus coloured and outer glumes colourless.

Variety XXXIV. *Unnamed New Type Z.*

(*d*) Inner glumes black.

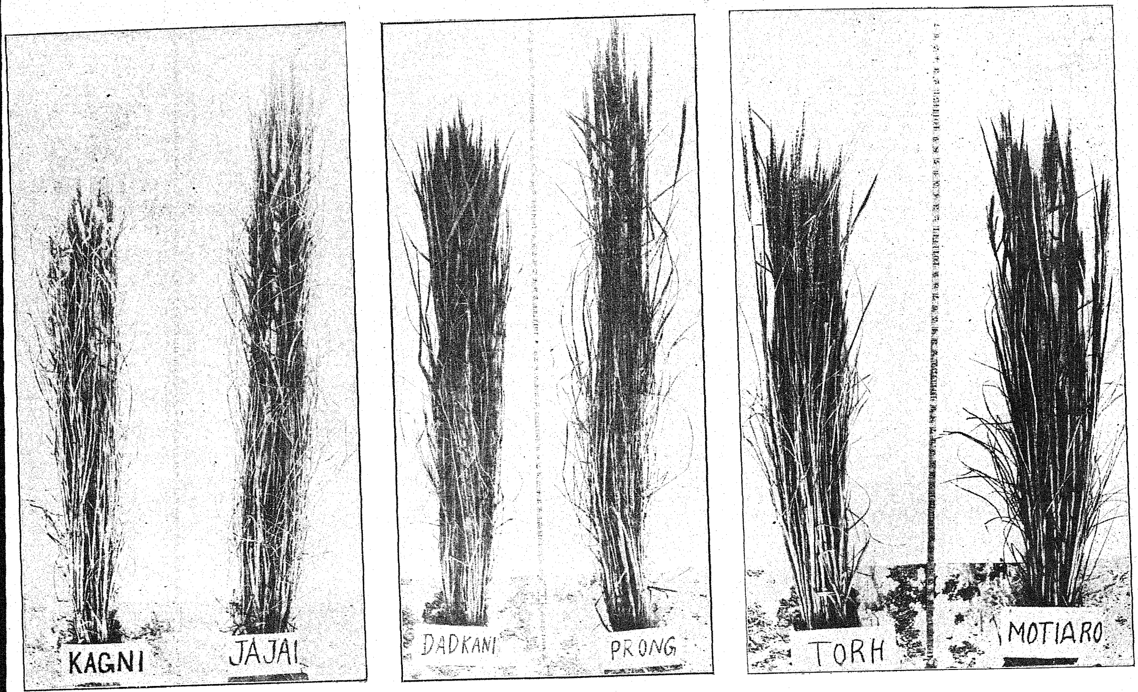
(ii) apiculus and outer glumes coloured.

Variety XXXV. *Unnamed New Type E.*

This table represents the whole of the types of rice which have reached the author's hands from various parts of Sind. It will be seen that they present great variety. Out of the thirty-five varieties twenty-three are beardless, and twelve bearded. The leaf sheath is green in twenty-one and red in fourteen cases. Twenty-five rices have white grains, and ten have red grains. Thirteen types are classed as coarse. Twenty-seven types were obtained in Upper Sind, and nine in Lower Sind.

DESCRIPTION OF RICE VARIETIES. The following notes indicate the status of each of these varieties in the cultivation of the crop.

PLATE I.



1. 2. 3. 4. 5. 6.

Prominent and high-yielding rice varieties of Upper Sind.

BEARDLESS VARIETIES.

I. *Parsad.* A sample of this variety was obtained from a Zemindar in the Larkana district. It is also known as *Sukh Parsad.* Its grain is fine and white, and it is *early.* The straw is strong. It is not grown on a commercial scale.

II. *Barsati.* This is a Lower Sind rice and was obtained from Tando Ghulam Hyder (Lower Hyderabad). It gives a fine white grain, is early and yields fairly well. It is not grown on a very large scale.

III. *Jirashahi.* This also comes from Hyderabad. Its grain is very small, hence its name which implies resemblance to a cuminseed. It ripens late, has strong straw and has a large tillering capacity. It is not grown on a commercial scale.

IV. *Jajai.* This is an important, scented, *sugdasi* variety ranking among the highest quality rices of Upper Sind. It usually brings a premium of Rs. 4 per maund of clean rice over *Kangni.* It is earlier than *Prong,* a *sugdasi* rice grown in the same area, but tends to lodge. The straw is very tough (and hence threshing is tedious), and it is not liked by cattle. The area under this variety is not very large, being chiefly in the Mirokhan and Kambar talukas of Larkana. Its yield is low compared to *Kangni* and *Prong.*

V. *Unnamed new type A.* This is a new *sugdasi* type discovered as a strong plant, which has a fine grain like *Jajai.* It is very early but is a poor yielder and shows much sterility.

VI. *Chajrai.* This is a Lower Sind rice, not grown on a large scale. Its grain is fine and white, but it is a poor yielder. It is a medium ripener.

VII. *Unnamed new type X.* This is a *Sugdasi* type found in a field of *Jajai,* ripening earlier than the latter. It is scented and yields fairly well, and the grain is fine and white.

VIII. *Red Kangro.* This is an early Upper Sind variety with a superior white grain, though with a red husk. The yield is higher than the common quick maturing types. It is not grown on a large scale.

IX. *Bidri.* This early rice, grown in Larkana on high lands, is a dwarf variety with a coarse grain. It can withstand a good deal of salt in the soil. It is grown on a fair scale on high lying lands.

X. *Sathri.* This variety, commonly grown on high lying lands in Upper Sind, is early ripening, but gives a poor grain, though its straw is much liked by cattle. It can withstand a good deal of salt in the soil.

XI. *Ratrya.* This is a variety common in the Nara valley, where it is known as Nara rice. It is also grown in the Tando area of Hyderabad under the name '*Khorwa*' rice. It is the best in quality of Lower Sind rices, giving a white medium quality grain and yields fairly well. It has a very light husk.

XII. *Ganjro.* This is a very early Upper Sind variety which is grown on high lands in small patches. Its grain is coarse, and the straw is brittle but much liked by cattle.

XIII. *Pista or Kariaro.* This variety is termed *Pista* owing to its small grain resembling a pistachio nut, and *Kariaro* on account of its black husk. It is an Upper Sind type, and is tall, late in maturity, and yields fairly well.

XIV. *Kangni.* This is the standard type of rice for Upper Sind, and is grown on all kinds of soils except those which lie low. The grain is white, medium in quality and the straw is good. It forms the staple food of the mass of the population, and is parboiled and then exported on a large scale.

XV. *Sathrya.* This is a type very similar to *Kangni* in the Nara Valley in Lower Sind. It gives a tall plant which lodges badly, matures early and only gives a small yield.

XVI. *Kunjro.* This Upper Sind variety is very rarely grown. It is late type, has a medium sized plant, with a white, small but coarse grain.

XVII. *Torh.* This is an important variety in Upper Sind for high lands, and it can withstand salt in the soil fairly well. It is a heavy yielder and has good straw, but sheds its grains badly. The grain is coarse and fetches a low price in the market.

XVIII. *Unnamed new type G.* This was found as a stray plant, with a fine red grain, in a field of *kangni* rice. It did not breed true, but a type as described has been isolated and maintained.

XIX. *Sindhi Kambroo.* This is an early variety from Lower Sind, with coarse red grains—not extensively grown.

XX. *Unnamed new type Y.* This was again found as a stray plant, and has been maintained. It is a type with a very heavy grain, yielding high and giving a coarse red grain.

XXI. *Ganja.* This is a Lower Sind variety grown on high lands, maturing earlier than *Motya* (*see* below). It lodges very badly, its grain is rather coarse and brittle and is very low priced.

XXII. *Lari.* This is an Upper Sind variety whose name implies that it was originally obtained from Lower Sind. It is grown on *low* lands, and the plant is tall and matures late. It lodges very badly. The grain is very poor and sells at a very low price.

XXIII. *Motya.* This is a low land variety from the South of the Hyderabad District. It is a tall plant and matures late. The grain is coarse, red and heavy, and fetches a low price. It is largely used in Hyderabad.

Bearded varieties.

XXIV. *Sighro.* This is an Upper Sind variety, early ripening and occasionally grown on patches on high lying land. The plants are not tall and the straw is much liked by cattle. The grain is fine and the yield fairly good.

XXV. *Sonahiri.* The colour of the husk of this rice is deep red, and it is obviously closely related to *Sada gulab* (*see* below), though later than the latter. It is an Upper Sind variety, which has a very light, thin, brittle grain. The plant tends to lodge badly,

XXVI. *Sada gulab.* This is a superior *sugdasi* variety in Upper Sind, with a rose coloured husk. The plants are tall and late in maturing. The grain is somewhat lighter than *Prong* and higher in quality than the latter but very brittle. It is not commonly grown.

XXVII. *Unnamed new type B.* This type, developed from a stray plant in Upper Sind, is a tall plant, late in ripening and has a long and heavy grain. The straw is strong. There is much sterility in the earheads. This is a scented variety.

XXVIII. *Unnamed new type C.* This is another type developed from a stray plant found in a field of *Prong* (Upper Sind). It has a fine white grain, but the yield is low.

XXIX. *Prong.* This is second only to *Kangni* in extent of cultivation in Upper Sind. It is tall, and matures much later than *Kangni.* The grain is long, thick and heavier than all the other *sugdasi* varieties. The straw is tough and not liked by cattle, and the grain is threshed with more difficulty than with other varieties.

XXX. *Bengalo.* This is a scented rice, better in quality even than *Jajai* (*see* below) but was obtained in Lower Sind. It ripens at the same time as *Jajai*, is a fairly high yielder and the grain is fine and white.

XXXI. *Motiaro.* This variety was obtained from Johi taluka in the south of the Larkana District, where it is much appreciated and fetches a good price. It is a low land variety, tall and matures late. The earhead is highly branched and well filled with coarse grains, looking like beads—hence its name.

XXXII. *Unnamed new type Z* A. This is a wild rice in Upper Sind, with a very luxuriant growth and a coarse red grain.

XXXIII. *Unnamed new type D.* This, again, was developed from a stray plant in a field of *Prong*, in Upper Sind. It has a coarse red grain and is a low yielder.

XXXIV. *Unnamed new type Z.* This is also a type from Upper Sind, with a very long, thick red grain. It ripens late, yields well, but the grain sheds badly.

XXXV. *Unnamed new type E.* Another wild rice from Upper Sind, dwarf in character; the leaves being very conspicuous with a dark margin. The grain is red and coarse w'th a black husk and black awns. The shedding is very great.

III. Characteristics of rice varieties in Sind.

It is proposed in the present section of this paper to consider the characteristics of a large number of the varieties of rice as above classified and described. Some of these characters are morphological, some are agronomic, and some physiological in character.

Morphological characters.

Awn characters of Sind rices. No feature is more variable among the rices grown in Sind than the awn character. Of the thirty-five Sind types collected, awns are

present on eleven varieties, most of which ripen late and all of which come from the drier conditions of Upper Sind. Where present, the awns have the same colour as the tip of the inner glumes. Most of the awned types have a generally vigorous growth, and the awns are valuable as a protection from pigs, birds, rats, and certain insects. They are associated with both fine and coarse rices, as the following table shows.

TABLE I.

Awn characters of Sind rices.

Variety	Awn character	Colour of		Character of rice
		Awn	Apiculus	
1. *Motiaro*	Very long Coarse, Erect.	Coloured	Coloured	Coarse, high yielding.
2. New Type Z	Long	Coloured when young.	Do.	Coarse.
3. New Type Z A.	Medium Coarse Erect.	Do.	Do.	Coarse: Kernel red.
4. *Sonahiri*	Long	Coloured	Do.	Fine scented rice.
5. *Sada Gulab*	Rather long	Do.	Do.	Do.
6. *Prong*	Medium	Do.	Do.	Do.
7. *Bengalo*	Do.	Do.	Do.	Do.
8. *Sighro*	Do.	No colour	No colour	Do.
9. New Type B.	Do.	Do.	Do.	Fine: white grain.
10 New Type D.	Do.	Do.	Do.	Coarse red grain.
11. New Type C.	Do.	Coloured	Coloured	Fine rice: white grain.

Colour relationship in Sind rice plants. (*a*). *The leaf sheath.* The colour of the leaf sheath is a useful character for diagnosis, as it can be seen in the seedling stage. The normal colour varies from yellowish-green or green to a shade of red or purple; it may be temporary or permanent. The majority of the Sind rices have a green leaf sheath; only seven out of the thirty-five types studied have it coloured. All the varieties with a green leaf sheath have a white grain kernel. The converse is not, however, true.

It has been stated by Graham (2) that the colour of the leaf sheath in rice is associated with a similar colour of the apiculus. This association does not, however, exist in the Sind types. The following table shows the colour of various organs in seventeen varieties of Sind rices.

TABLE II.

Colour relationships in Sind rices.

Variety	Presence of Red Colour in			Colour of Inner glumes and paleae.	Colour of kernel
	Leaf sheath	Apiculus	Outer glumes		
1. *Kangni*	Present	Present	Absent	White	White
2. *Sathrya*	Do.	Absent	Do.	Do.	Do.
3. *Kunjro*	Do.	Do.	Do.	Do.	Do.
4. *Torh*	Do.	Do.	Do.	Do.	Do.
5. New Type G.	Do.	Present	Do.	Do.	Red.
6. *Sindhi Kambroo*	Do.	Absent	Do.	Do.	Do.
7. New Type Y	Do.	Present	Do.	Do.	Do.
8. *Ganja*	Do.	Do.	Do.	Do.	Do.
9. *Motya*	Do.	Do.	Do.	Do.	Do.
10. New Type Z a.	Do.	Do.	Present	Do.	Do.
11. New Type E.	Do.	Do.	Do.	Black	Do.
12. *Ratrya*	Absent	Do.	Do.	Red	White.
13. *Pista*	Do.	Do.	Do.	Black	Do.
14. *Prong*	Do.	Do.	Do.	Yellow	Do.
15. *Sonahari*	Do.	Do.	Do.	Red	Do.
16. *Sadu Gulab*	Do.	Do.	Do.	Do.	Do.
17. *Motiaro*	Do.	Do.	Do.	Yellow	Do.

(*b*). *Inner glumes.* The colour of the inner glumes (*paleae* and *lemma*) may be white, yellow, red or black, though each group includes many shades. The colours for each variety are constant and form a diagnostic character. It may be noted, too, that the prominence of the ridges and grooves on the surface of the inner glumes is characteristic of the varieties. They are usually prominent in coarse varieties and faint on slender rices.

(*c*). *Apiculus.* The apiculus or the tip of the inner glumes may or may not be coloured, and the colour may be temporary or permanent. Thus a distinctly coloured tip at the time of flowering has been noticed, where the colour fades as the plants approach maturity. On the other hand, some varieties show a green tip at flowering where colour developes as the grain matures. As already stated, the colour of the *apiculus* is *not* constantly associated among Sind rices with the colour of the leaf sheath or of the outer glumes.

Height of the main culm. The variation of the height of the main culm was only measured *within* each of the three main varieties studied, namely, *Kangni*, *Jajai*, and *Prong* when grown under similar conditions at one place (Larkana). The height

was measured from the ground to the tip of the topmost spikelet, and between 450 and 500 plants were examined in each case. The mean height in these three varieties was as follows :—

	Inches.
Kangi	51·4±·14
Jajai	55·6±·42
Prong	51·7±·44

Generally, short varieties are low yielders, but when the height is greater than 42 inches, added height is not associated with heavier yield. High varieties are, in general, more liable to lodge. *Jajai* lodges badly and the types accustomed to submergence in water (*Lari* etc.) lodge still more seriously. Among the *sugdasi* varieties, *Prong* lodges less than the others.

Tillering capacity. As a rule, tillering in rice plants commences a fortnight after transplanting and continues for two or three weeks. Under deep water conditions, such as prevail in the rice swamps of the Lar tract, tillering is very largely prevented.

While the *relative* number of tillers is a character which is characteristic of varieties, and especially of strains of varieties, yet the amount of tillering varies in different years, probably owing to variations in the manner of water supply and the land on which they are grown. This is illustrated by the following figures for two pure strains of each of the varieties *Kangni*, *Jajai* and *Prong* at Larkana. The figures are based on the examination of 50 plants in 1924, 250 plants in 1925, and 500 plants in 1926.

TABLE III.

Number of tillers in plants of selected strains.

Variety and strain		Number of tillers per plant (mean)		
		1924	1925	1926
Kangni strain	27	11·6±·34	19·4±·25	9·6±·15
	43	10·5±·28	17·8±·32	11·0±·17
Jajai strain	77	10·5±·22	20·3±·38	11·7±·19
	43	12·9±·23	21·2±·39	13·0±·17
Prong strain	36	13·7±·25	20·3±·37	14·5±·18
	51	12·5±·27	17·4±·27	11·8±·15

So far as the varieties, as they occur in cultivation, are concerned, the tillering capacity is of course much more variable than the above, and the late varieties are, on the whole, distinctly more highly tillering than the early ones, though there are exceptions. The following tables show, for the early and late rices separately, the relative tillering capacity under similar conditions for three years. The figures for 1924 and 1925 are based usually on the examination of from 130 to 150 plants, and those for 1926 on 500 plants.

TABLE IV.

Number of tillers per plant in early varieties.

Variety	Mean number of tillers per plant		
	1924	1925	1926
1. *Kariaro*	9·4	..	—
2. *Barsati*	9·8	8·9	—
3. *Bengalo*	10·0	..	—
4. *Sighro*	10·7	12·9	—
5. *Sindhi Kambroo*	12·7	9·5	—
6. *Parsad*	13·0	..	—
7. *Chajrai*	13·2	11·3	—
8. *Kangni* (strain 14)	13·2	..	—
9. *Ganjro*	14·6	9·9	—
10. *Sathri*	14·7	9·8	—
11. *Bidri*	1·50	11·0	—
12. New Type A.	15·2	9·7	—
13. *Motiaro*	15·8	13·8	—
14. *Red Kangro*	20·4	..	—
15. *Torh*	21·6	18·3	22·0

Taking these early rices it will be seen that *Torh* stands out as a high tillering rice in each year.

TABLE V.

Number of tillers per plant in late varieties.

Variety	MEAN NUMBER OF TILLERS PER PLANT.		
	1924	1925	1926
1. *Ganja*	13·3	—	—
2. New Type Z a.	13·5	—	—
3. *Lari*	13·8	16·8	—
4. *Pista*	14·4	—	—
5. *Prong* (Strain 65)	16·0	16·5	—
6. *Sonahari*	16·1	10·1	—
7. *Sada Gulab*	16·9	11·1	—
8. *Kunjro*	17·0	17·9	—
9. New Type B.	19·4	—	—
10. *Jirashahi*	20·5	..	23·2
11. *Motya*	..	9·3	—

Taking the rices actually in cultivation, it will be seen that *Jirashahi*, and *Kunjro* stand out as giving a constantly high tillering capacity among these late Sind varieties.

In 1925, a large number of foreign varieties, brought either from other parts of India or from other rice growing countries, were grown under similar conditions to the types indicated above, and their tillering capacity determined. They were transplanted as single plants, 12 inches by 9 inches apart, on July 22, 1925. The tillering capacity of these varieties was as follows. The details are given in Appendix A.

(1) *Konkan rice varieties.* The strains of the Kolamba rice of the Konkan, isolated at Karjat, gave from 14·7 to 20·9 tillers per plant, corresponding closely to the late Sind varieties.

(2) *Bengal rice varieties.* Six varieties were tested from Bengal, and these gave from 9·6 to 31·7 tillers per plant. The high varieties were *Indrasail* with 30·6 and *Dadkani* with 31·7 tillers. The former of these is one of the very high yielding *aman* rices of Bengal.

(3) *Assam rice varieties.* In tillering capacity, the fifteen varieties of Assam rice were similar to the samples from Bengal, varying from 8·6 to 30·5 tillers per plant. The highest varieties are *Indrasail* with 29·1 tillers, *Tipidumia* with 30·3 tillers and *Negrasail* with 30·5 tillers per plant.

(4) *Central Provinces rice varieties.* None of the eight rices tested from the Central Provinces, except one had a high number of tillers per plant.

This one was a variety named *Khut bhara* which gave 25·6 tillers per plant.

(5) *Dacca deep water rice varieties.* These plants were not in their element as it was not possible to supply them with enough water, and hence they were somewhat sickly. Under these conditions none of the three varieties tested gave more than 16·0 tillers per plant.

(6) *Japan rice varieties.* Ten varieties from Japan were tested. All of these were dwarf types, and the tillering was delayed. No grain was produced in any of them though the spikelets were normal in appearance. Most of them gave very few tillers, six of them giving from 6 to 10 tillers per plant. The highest (*Oba*) only gave 16·6 tillers per plant.

Length of earhead and number of branches in panicle. The length of the earhead and the number of branches in the panicle was studied for twenty-six Sind varieties grown under similar conditions in 1923, measurements being taken (except in the new unnamed types) of between 100 and 200 heads in each case. The actual figures are given in Appendix II. There is, of course, nothing absolute about the figures though they are comparable among themselves. The length of the earhead in Sind types varied from seven to ten inches and the number of branches in the panicle from eight to eleven. The longest ear with the greatest number of panicle branches was possessed by the *Motiaro* variety, a bearded, medium ripening type from the Johi taluka of the Larkana District (*see* above). This gave in 1923 an earhead with an average length of 10·2 inches, and an average of 17·6 branches per panicle.

A much more detailed examination of these characters was undertaken with the three varieties (*Kangni, Jajai* and *Prong*) selected for special study. In 1922 over one thousand earheads were examined in each case, and in 1923 nearly five hundred.

TABLE VI.

Earhead characters of selected Sind rice varieties.

Variety		Number of ear heads examined	Mean length of earhead inches	Mean number of branches
1. *Kangni*	1922	1780	8·3	8·7
	1923	448	8·2	9·6
2. *Jajai*	1922	1100	11·6	9·6
	1923	479	11·1	9·2
3. *Prong*	1922	1100	11·6	9·8
	1923	480	10·2	8·9

These figures show the very large variations in the density of the earheads. *Kangni*, though having a short earhead contains an equal number of branches per panicle with the other two types examined.

Number of spikelets per earhead in Sind rices. Jacobsen (6) in a report on Philippine rices, shows that, grown under similar conditions the number of spikelts per earhead varies in that country from 50 to 478. The range in Sind does not seem quite so great, but in tests of twenty-five varieties in 1923, all grown together at Larkana, a range of 92 to 303 was found. The detailed figures are given in Appendix III. It will be seen that *Jirashahi*, a variety from Hyderabad, stands highest with 303 spikelets per earhead, but the grain of this variety is very small. It is also the case with the other varieties with a large number of grains per earhead, such as *Kunjro* (254 grains), *Pista* (206 grains) and *Motiaro* (196 grains). Some fine grained varieties from the Konkan and Bengal, grown under similar conditions in the same season, gave similar figures. Thus Kolumba No. 42 and Kolumba No. 79 from the Konkan gave 203 and 231 grains respectively per earhead. A fine Bengal rice gave 124 grains, and the *Dadkani* variety from Bengal gave 203 grains per earhead.

Weight of grains in Sind rices. Most of the Sind varieties of rice have large heavy grains. The rice growers are not familiar with the finer, lighter grain types; they have, in fact, a prejudice against them, especially when they are not suitable for parboiling. As a rule, heavy grain varieties mill better than light ones.

The types may be classified into light (1·5 grams or less per 100 grains), medium (1·5 to 1·9 grams per 100 grains), heavy (2·0 to 2·5 grams per 100 grains), and very heavy (above 2·5 grams per 100 grains). Out of a large number of Sind types examined the results may be summarised as follows :—

(1) *Light grained types. Kunjro, Jirashai, Dadkani* and *Pista.* Weight varied from 0·92 grams (*Kunjro*) to 1·13 grams (*Pista*), per 100 grains.

(2) *Medium grained types. Jajai, Motiaro, Sighro, Red Kangro, Sathri, Parsad, Bidri.* Weight varied from 1·84 (*Bidri*) to 2·1 (*Jajai*) grams per 100 grains.

(3) *Heavy grained types. Prong, Ganjro, Ratrya, Sonahiri, Torh, Kangni,* and *Sada Gulab.* The weight varied from 2·2 (*Sada Gulab*) to 2·4 (*Prong*) grams per 100 grains.

(4) *Very heavy grained types. Ganja* and *Lari.* The weight in these cases was 2·9 (*Ganja*) and 3·0 (*Lari*) grams per 100 grains.

To make clear the meaning of these figures it may be stated that Copeland (3), from Philippine experience, takes 2·0 grams per 100 grains as the grain weight of ordinary commercial rices. The fine rices of Western India and Bengal, however, are much smaller. Two strains of (Konkan rice *Kolamba*) from Karjat, grown in Sind, gave 1·3 and 1·0 grams per 100 grains respectively, and a Bengal rice gave 1·95 grams per 100 grains.

AGRONOMIC CHARACTERS.

Yielding capacity of Sind rices. In all questions of improving farm crops, the paramount importance of maintaining a high yield must always be fully recognised. The yield is, in the case of rice, obviously a complex of many factors, such as tillering power, number of grains per earhead, sterility percentage in the panicle, and a special difficulty in the study of the capacity to yield in the case of the various varieties is the very great variability from year to year. In spite of this difficulty, however, the results of several seasons show that high yielding types, on the whole, maintain their superiority from year to year. This is still more the case in selecting strains out of the different varieties. In the intensive study of the *Kangni*, *Jajai* and *Prong* varieties, it has been possible to isolate strains which for several years have consistently given high yield, and in which yielding power behaves as a hereditary character. These will be dealt with later. In the meantime, some idea of the position with regard to the plants of the Sind varieties, as grown side by side at Larkana, may be given.

In 1923, twenty-six distinct varieties of Sind rice were under trial, being planted in a similar manner in each case. Ten single plants of each were harvested separately and from these it was found that the average yield per plant varied from 19 to 58 grams. *Torh*, *Motiaro* and New Type Y were found to be very heavy yielders. When the yield *per earhead* was taken, the same varieties stood at the top of the list. In 1924 and succeeding years a large number of plants (generally over 100) of each variety were examined, but in each year same varieties have maintained their position. Detailed results of the yield are given in Appendix IV, with those of a number of rices from other parts of India and from Japan, grown under similar conditions in 1925.

Period of growth in Sind rices. The time required by a variety of rice to come to maturity is a matter of very great importance, especially in a country where the time during which water is available is limited. The character of inundation season in Sind is very uncertain: when the season is shortened, the essential requirement of an efficient variety is speed of growth. Varieties which are late in ripening cannot always succeed and are hence useless. Of course, as would be expected, the length of the growth period varies a good deal with the area in which a particular variety is grown. Thus the Upper Sind variety *Prong*, which is late in its own area, matures much more quickly in Lower Sind. On the other hand, *Kangni*, the favourable early variety of the Larkana district has its period of growth increased in Lower Sind. The Lower Sind type *Ganja* was found to mature considerably later in Larkana than in its own area. Further a very early variety of rice from Ratnagiri (Konkan) was found to take a much longer time for ripening in Larkana. These variations are, of course, in accordance with what has been found elsewhere, and all comparisons of time required for growth have, in the present paper, been made on the basis of cultures on similar land at Larkana in Upper Sind.

In rice some varieties flower in a definite length of time, more or less irrespective of their date of sowing and transplanting : others flower, every year, at a particular time, no matter whether they are transplanted early or late. The former mode of flowering has been termed, 'periodically fixed' and the latter 'timely fixed' by Mitra (8). The following varieties of rice belong to the former class :—(1) *Kangni*, (2) *Sathri*, (3) *Ganjro*, (4) New Type A and this is shown by the records of 1923, 1924 and 1925.

TABLE VII.

Time of flowering of 'Periodically Fixed' types of rice.

Variety		Date of transplanting	Number of days transplanting to flowering
Kangni	1923	June 28, 1923	78
	1924	July 16, 1924	78
	1925	July 11, 1925	80
Sathri	1923	July 7, 1923	65
	1925	July 21, 1925	62
Ganjro	1923	July 8, 1923	55
	1925	July 21, 1925	51
New Type A.	1923	July 8, 1923	48
	1925	July 21, 1925	47

The 'timely fixed' varieties of rice in Sind seem much more numerous, and among these it will be found that the dates of flowering will be hardly affected by the date of transplanting. The following table shows this.

TABLE VIII.

Time of flowering of 'Timely Fixed' types of rice.

Variety		Date of transplanting	Date of flowering	Number of days transplanting to flowering
Sighro	1923	July 8, 1923	September 11, 1923	65
	1925	July 21, 1925	September 12, 1925	54
	1926	July 7, 1926	September 12, 1926	67
Bidri	1923	July 8, 1923	September 11, 1923	65
	1925	July 21, 1925	September 11, 1925	53

Time of flowering of 'Timely Fixed' types of rice—contd.

Variety		Date of transplanting	Date of flowering	Number of days transplanting to flowering
New Type B.	1924	July 23, 1924	October 2, 1924	71
	1925	July 7, 1925	October 3, 1925	88
Jirashahi	1924	July 23, 1924	October 24, 1924	93
	1925	July 12, 1925	October 22, 1925	102
Torh	1923	July 8, 1923	September 29, 1923	83
	1925	July 21, 1925	October 3, 1925	74
Jajai	1923	June 28, 1923	October 4, 1923	98
	1924	July 16, 1924	October 9, 1924	84
	1925	July 11, 1925	October 4, 1925	85
Prong	1923	June 28, 1923	October 10, 1923	105
	1924	July 16, 1924	October 17, 1924	94
	1925	July 11, 1925	October 8, 1925	90

In determining the earliness of varieties of rice, early flowering is usually considered as an index of early maturity. This is, however, not strictly true: for the interval between flowering and maturity has been found to vary considerably. In fact, among Sind varieties, the time from flowering to maturity varies from 24 to 53 days. The variation is much more limited than if varieties from other parts of India and abroad are included: a number of these grown at Larkana showed variation from ten to eighty days, Philippine varieties (Crisostomo 15) varied from eleven to sixty-nine days.

The interval between flowering and maturity varies from season to season not only with the same variety, but also with the same strain, of rice. In 1923, for instance, it was much shorter than in 1924 and 1925 at Larkana with selected strains from *Jajai* and *Prong* rices. The actual mean figures for four strains were as follows:—

TABLE IX.

Seasonal variation in the ripening period.

Strain		Number of days from flowering to maturity		
		1923	1924	1925
Jajai	No. 77	20·7	29·9	30·2
	No. 43	22·9	31·9	31·4
Prong	No. 36	27·7	34·2	30·7
	No. 51	28·7	32·0	32·1

In assigning values, therefore, in terms of days required to mature, the time of sowing and transplanting is very important with varieties whose flowering is 'timely fixed' though of less account with those whose flowering is 'periodically fixed.' Further, the variation from season to season must be kept in view. With these limitations, however, the figures obtained for the period from transplanting to flowering and for the total life period in 1925 and 1926 are of value. They at least show a similar relationship *between the varieties* in the two years.

TABLE X.

Flowering and ripening period of Sind varieties.

Variety	1925			1926		
	Days from transplanting to flowering	Days from transplanting to ripening	Days for ripening	Days from transplanting to flowering	Days from transplanting to ripening	Days for ripening
A. Early varieties—						
Red Kangro	53	83	30	63	100	37
Sighro	54	88	34	61	100	39
Bidri	53	92	39	—	—	—
Ganjro	57	92	41	—	—	—
Barsati	59	97	38	—	—	—
New type A.	47	100	53	—	—	—
Sathri	62	100	38	—	—	—
Sindhi Kambroo	58	101	43	—	—	—
Kangni No. 27	78	102	24	72	112	40
B. Medium varieties—						
Torh	74	108	34	81	113	32
New type Y.	69	108	39	77	115	38
Sada Gulab	67	108	41	—	—	—
Sonahiri	67	108	41	—	—	—
Motiaro	81	110	29	86	125	39
Jajai	84	116	32	77	128	51
Chajrai	66	119	53	—	—	—
Bengalo	75	119	44	85	128	43
C. Late varieties—						
Ganja	71	121	50	—	—	—
Lari	72	121	49	—	—	—
Kunjro	84	121	37	—	—	—
Ratrya	82	123	41	—	—	—
Prong	93	126	33	88	131	43
Motya	86	131	45	—	—	—

Corresponding figures for a number of foreign varieties as grown in Sind are given in Appendix V.

IV. Quality among Sind varieties of rice.

Quality in rice is related to a number of characters of the grain, of which the chief are (1) the size and shape of the grain and kernel, (2) the colour of the kernel, (3) the hardness of the kernel, (4) the percentage of hull, (5) the flavour and cooking qualities. These will be dealt with in succession as applied to Sind rice.

1. *Size and shape of the grain and kernel.* In India rices are bought and sold on the character of the grain and a general preference is shown for rice which has a slender grain. All so-called coarse rices have a broad grain, and so slenderness is an essential for a rice to be counted as fine. As regards the length of the grain, opinions differ as to whether a long grain is to be preferred to a short grain, but the consensus of opinion is that a long slender grain is a finer rice, and so this commands a larger price in the market.

Graham (2) divides grains of rice into four classes :—

(1) Long spikelets, when the length is more than four times the breadth.
(2) Fine spikelets, when the length is more than three times the breadth.
(3) Coarse spikelets, when the length is more than twice the breadth.
(4) Round spikelets, when the length is less than the breadth.

Classified in this manner some of the Sind varieties stand as follows :—The figures indicate the length divided by the breadth.

(1) *Long rices, Dadkani,* (4·14), *Prong* 65 (4·10) *Sighro* (4·18), *Red Kangro* (4·12). A long Konkan rice (*Kolamba* 79) grown in Sind gave 4·21 as the proportion between length and breadth.

(2) *Fine rices, Bengalo* (4·02), *Sonahiri* (4·05), *Jirashahi* (3·86), *Chajrai* (3·83), *Parsad* (3·81), *Kangni* 14 (3·78), *Jajai* (3·71), *Barsati*, (3·60), *Bidri* (3·41), *Sathri* (3·38). A fine *Kolamba* rice (*Kolamba* 42) grown in Sind, gave 3·41 as the proportion between length and breadth.

(3) *Coarse rices Lari* (2·99), *Torh* (2·92), *Sindhi Kambroo* (2·81), *Motiaro* (2·69), *Pista* (2·43), *Kangro* (2·27).

Though the ratios just given indicate the fineness or coarseness of the rice, the actual length and breadth of the various types is a matter of some importance, and the following figures relating to the principal varieties are therefore interesting. They relate to the crops of 1925, but there is little change from year to year :—

(*a*) *Long grained rice.* (These include those whose length of grain is above 8·9 mm.) New Type Z (10·2 mm.), *Sighro* (9·6 mm.), *Kangni 14* (9·4 mm.), *Sonahiri* (9·3 mm.), *Prong* 65 (9·2 mm.), *Lari* (9·1 mm.), *Barasati* (9·0 mm), *Bengalo* (9·0 mm.)

(*b*) *Rices with grains of medium length.* (These include those whose length of grain lies between 7·9 and 8·9 mm.) *Chajrai* (8·9 mm.), *Sindhi Kambroo*

(8·8 mm.), *Ganja* (8·7 mm.), *Jajai* 63 (8·6 mm.), *Bidri* (8·5 mm.), *Parsad* (8·4 mm.), *Red Kangro* (8·2 mm.), *Sathri* (8·1 mm.).

(c) *Rices with short grains.* (These include those whose length is below 7·9 mm.) *Dadkani* (7·8 mm.), *Motiaro* (7·5 mm.), *Jirashahi* (6·9 mm.), *Pista* (5·6 mm.), *Kanjro* (5·4 mm.).

With regard to breadth of grain, the varieties may be classified as follows. The measurement refers to the position of the grain as it lies in the table, and represents the maximum breadth.

(a) *Rices with slender grains.* (These include those with a grain breadth of less than 2 mm.) *Jirashahi* (1·8 mm.).

(b) *Rices with oval grains.* (These include those with a grain breadth of 2 to 2·5 mm.) *Bidri, Kangro, Sighro, Jajai, Barsati, Sathri, Sonahiri, Chajrai, Parsad, Kangni, Prong, Pista, Bengalo, Red Kangro.*

(c) *Rices with flat grains.* (These include those with a grain breadth of more than 2·5 mm.) *Ganja, Sindhi Kambroo, Lari, Motiaro, Ganjro, Torh.*

It will be noticed from the above, and the description of the varieties given on page 118 that nearly all the commercial varieties of Upper Sind, including *Kangni*, the *Sugdasi* varieties and *Sathri* are oval grained and hence highly valued for quality on the market. The Lower Sind varieties are mostly flat grained, and hence are valued lower. Exceptions are the *Torh*, and *Motiaro* varieties in Upper Sind which are flat grained, but are grown for their high yield. Slender rices are practically unknown in Sind, and have little or no market.

Size of kernel. The size of the kernel, that is to say, of the grain after shelling has been usually considered to correspond approximately with the size of the grain Graham (2) Copeland (3). This does not apply in the case of a number of Sind rices owing to very considerable variation in the thickness of the husk. The following figures for pure lines of three varieties of Upper Sind rice show this clearly.

TABLE XI.

Grain and kernel measurements.

Variety and strain.	MEAN LENGTH OF		MEAN BREADTH OF		RATIO, TO LENGTH BREADTH	
	Grain	Kernel	Grain	Kernel	Grain	Kernel
	mm.	mm.	mm.	mm.		
Kangni 43	8·9	6·3	2·4	2·0	3·7	3·1
Jajai 43	8·0	5·9	2·3	1·8	3·5	3·3
Prong 36	9·4	7·2	2·4	2·0	3·9	3·5

2. *Colour of the kernel.* The kernel colour of rice may be red or white, though the white rices really vary from pale yellowish white to deep yellow. In-as much as

the world's commerce demands white rice, other things being equal, white rice is always preferred even in India. Out of the thirty-five Sind varieties described, only ten have red grains, namely *Ganja, Lari, Motya, Sindhi Kamroo* and six new types obtained as stray plants in the crop. The red grained rices are, in fact, usually very coarse and are often found as weeds in cultivated rices. They greatly lower the value of white rice by their presence. The variety *Motya* is, however, very well suited for parboiling. The red colour is superficial in all the Sind rices, and can be removed by proper milling.

3. *Hardness of the kernel.* Rice is described as hard or soft according to the appearance of the cut surface of a grain cut across the middle. Grains with a shiny translucent surface are termed hard; those with a dull white appearance are soft. The former mill better and stand shipment better than the latter, and while the latter tend to form a sticky mass when cooked, the former retain each kernel separate. The hard types are therefore considered to be of much higher quality.

The rice varieties of Sind may be classified in respect to this character as follows :—

(1) *Entirely hard*—All *sugdasi* varieties, *Parsad, Red Kangro, Barsati, Pista, Jirashahi, Bengalo.*

(2) *Partially hard*—*Kangni, Torh, Motiaro, Ratrya, Kunjro, Chajrai, Sighro, Bidri.*

(3) *Soft or opaque*—*Lari, Ganja, Sindhi Kambroo, Ganjro, Sathri.*

4. *Percentage of husk on the rice grain.* The proportion of husk may vary with different varieties grown under similar conditions from little over 18 to over 22 per cent. The light shelled varieties, giving from 18 to 19·5 per cent. of husk at Larkana in 1925, are *Sathri, Kangni, Ratrya, Prong, Motiaro* and *Sighro.* Medium shelled types with between 20 and 21 per cent. of husk are *Red Kangro, Sonahiri, Sada Gulab, Ganjro, Bidri* and *Jajai.* The heavy shelled types, with over 21 per cent. of husk, are *Dadkani, Parsad, Ganja, Jirashahi, Torh, Pista, Kunjro* and *Lari.* It may be noted that the Konkan *Kolamba* rices grown at Larkana classed as medium shelled types.

Flat and slender rices appear usually to be heavy shelled.

5. *Flavour and cooking qualities.* The so-called "*Sugdasi*" varieties of rice in Sind derive their name from the presence of flavour and aroma in the grain and in the plant, "*Sugand*" meaning flavour in Sindhi. Graham describes this fragrance as a mouse-like smell possessed by the grain and also noticed when the rice is in flower in the field. It is usually not appreciated by Europeans, but is held in high esteem throughout India. The *Jajai* variety is the typical *Sugdasi* rice, but even among types of this variety there is a difference in this respect, for the type known as "*Ghogharo*" grown in the village of that name, is said to be better in this respect than any other, and to lose a portion of its fragrance if grown elsewhere. No careful tests on this point have, however, as yet been made.

In addition to their flavour and aroma, the *sugdasi* varieties have good cooking qualities, as, for instance, they are said to swell up on boiling to an extent that no other rice does. They are also reputed to need less *ghi* (clarified butter) in cooking than the coarser types.

The best known *sugdasi* rices are *Jajai* and *Prong* of Northern Sind, but the following varieties are also considered to come within the *sugdasi* group, *Sonahiri*, *Sada Gulab*, New Type A, and *Bengalo*.

V. Flowering and pollination among Sind rices.

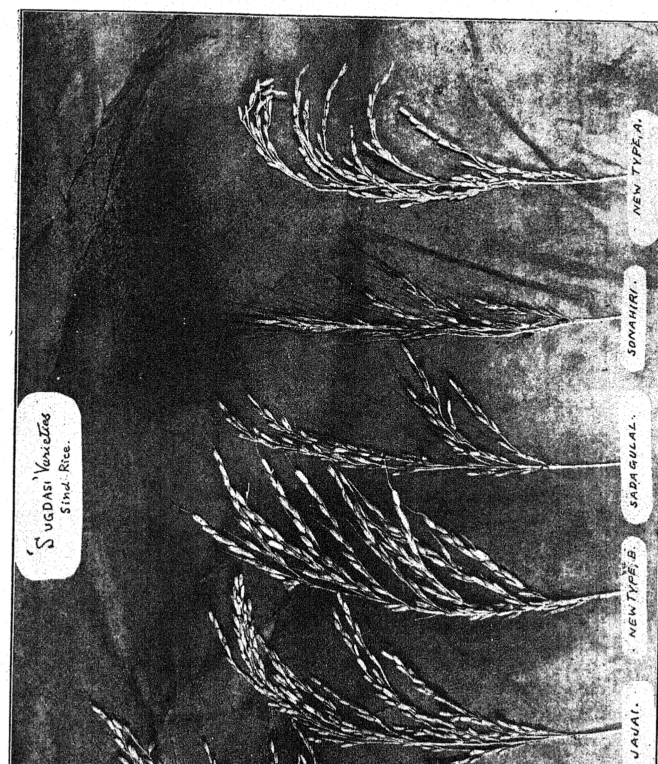
The process of opening the flower and pollination shows considerable variation in different places. In Italy, Farnetti (18) reports that the flowers are almost always cleistogamous and the glumes remain closed throughout. Elsewhere three cases have been described, namely, the dehiscence of the anthers (1) before the opening of the glumes (2) at the same time as the opening of the glumes and (3) after they have emerged and are in a pendent position. The first two cases ensure self-fertilisation : the last makes cross-fertilisation possible : all the cases occur among Sind rices, though the proportion in which each occurs varies a good deal with different varieties. For example, in the *Motiaro* variety as grown at Larkana nearly half the number of spikelets were cleistogamous.

As regards the opening of the flowers in the various parts of the earhead in Sind, the flowers at the tip of the inflorescence are usually the first to open, and the opening continues in regular downward succession. This forms the general rule, but in some cases, flowers in the middle of the ear open first and opening continues both upward and downward.

A close study has been made of the opening of the flowers on single earheads in a large number of varieties of rice in two seasons, and embraces the observation of the period (number of days required for the opening of all the flowers on the earhead) and also of the time of day when the opening took place. Full details of these observations with ten varieties in 1922, and of twenty-three varieties in 1924, are given in Appendix VI. The general conclusions may be summarized here.

1. As grown at Larkana all varieties open their flowers early in the morning, and the process closes shortly after midday. The actual pro ress of flowerin ; in ten ve ieties taken together in 1922 is shown in the following figures from 1,250 flowers examined.

	No.	Per cent.
Flowers opened before 7-30 a.m.	*nil*	
,, ,, 7-30 to 8-30 a.m.	3	0·24
,, ,, 8-30 to 9-30 a.m.	53	4·24
,, ,, 9-30 to 10-30 a.m.	399	31·92
,, ,, 10-30 to 11-30 a.m.	626	50·08
,, ,, 11-30 a.m. to 12-30 p.m.	141	11·28
Flowers did not open	28	2·24
TOTAL	1,250	



Sugdasi rice varieties of Upper Sind.

Similar figures for 23 varieties in 1924 gave figures as follows :—

	No.	Per cent.
Flowers opened before 7-30 a.m.	81	2·5
" " 7-30 to 8-30 a.m.	118	3·7
" " 8-30 to 9-30 a.m.	210	6·6
" " 9-30 to 10-30 a.m.	332	10·0
" " 10-30 to 11-30 a.m.	689	21·5
" " 11-30 a.m. to 12-30 p.m.	902	27·8
" " 12-30 to 1-30 p.m.	508	15·9
" " 1-30 to 2-30 p.m.	180	5·6
Flowers did not open	130	4·1
Abnormal spikelets	25	0·8
Rudimentary spikelets	8	0·3
Cleistogamous spikelets	43	1·3
TOTAL	3,226	

The actual range of time varies a little, as would be expected, from season to season, according to the climatic conditions of the season, and the different varieties vary much among themselves. Thus in the *Parsad* variety the bulk of the opening took place in 1924 before 8-30 a.m. On the other hand, in the *Ganjro* variety there was hardly any opening of the flowers before 10-30 a.m. The time of flowering for the whole of the varieties studied in 1922 and 1924 is shown in the graph in Figure 2.

2. The time of the day at which the rice plant flowers is partly determined by the date at which flowering takes place. The early varieties start flowering earlier in the morning than the later ones. Thirteen varieties studied in 1924 which flowered between September 8 and October 7 all began flowering at 7-30 a.m. Six varieties, whose flowering took place in the following month (8th to 23rd October) commenced opening the flowers not before 8-30 a.m. The four late types (whose flowering occurred between October 29th and November 9th) only began to open their flowers at 9-30 a.m. This difference was not purely a matter of temperature, as the opening of flowers commenced at a different temperature with the different varieties. The following figures show this :—

Variety	Date of flowering	Hour when flowering began	Air temperature
Parsad	September 14, 1924	7-30 a.m.	84°F.
Dadkani	October 17, 1924	8-30 a.m.	71°F.
Kunjro	October 29, 1924	8-30 a.m.	65°F.
Jirashahi	November 3, 1924	9-30 a.m.	70°F.

No flowers have been observed to open before daylight.

The closing of the flowering on each day again varies with the variety, but is earlier in the case of the early varieties than with the later ones. In no case does flowering continue after 2-30 p.m.

3. The flowering of a single earhead at Larkana continues for a period of from five to eleven days. The actual period observed for ten varieties in 1922 was from five to seven days, and for twenty-three varieties in 1924 was from five to eleven days. The progress of flowering during this period is shown in Figure 3. These figures may be compared with those noted by Thompstone and Sawyer (20) in Burma where the period of flowering ranged from seven to ten days.

The maximum flowering activity is reached in the second and third days of this period. There does not seem to be any relationship between the earliness or lateness of flowering and the number of days during which flowering continues.

4. The actual course of the opening of a flower is similar in Sind to that which has been described elsewhere. The glumes open very gradually and when the limit of divergence has been reached, convergence commences at once, until the act of closing is complete within about an hour, the time varying from 32 to 70 minutes.

VI. Sterility.

It would seem that the rices grown in all countries have a certain proportion of the spikelets in almost every head which never fill, and which, in fact, are sterile. But, in certain seasons, with the same varieties, the number of spikelets which does not produce grain increases very considerably and becomes what is usually considered by the people as a veritable disease. This is termed *Khas* in Sind and the term is applied to any condition in which the grain fails to an abnormal extent to set or to mature; wholly sterile heads are rare in Sind even in a year when *khas* is prevalent. The corresponding condition is known as *brusone* in Italy, *falla* in Spain, *imotsi* in Japan, *tiem* or *tim* in Cochin China, *gwabo* in Burma and perhaps as *mentek* in Java.

It is obvious that this term includes sterility due to a number of different causes. For instance, in every variety studied during the last three seasons, there are always some spikelets of the earhead, which do not reach full growth. These are, as a rule, situated in the lower part of the earhead. They dry up quickly and drop two to three days after emergence. These may be termed "*rudimentary*" spikelets.

Some of the spikelets, however, reach full size, but are incomplete,—one or both the reproductive organs being either absent or undeveloped. In many cases the anthers are shrivelled. They look distinctly white and remain on the ear during the green stage, but ultimately shrivel up and drop. These will be referred to as "*abnormal*" spikelets.

The remaining spikelets are at first apparently normal, and possess fully developed flower parts. As flowering proceeds, however, some of them fail to open their glumes and do not set grain. They may be called "*cleistogamic*" spikelets; others

Time of the day when opening of flowers takes place.

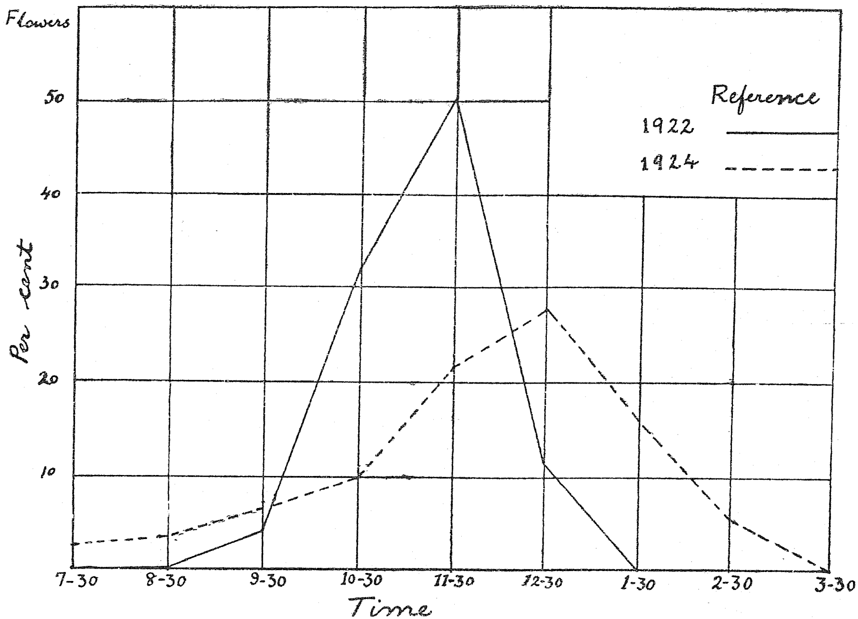


Fig. 2.

Period of flowering of a single earhead.

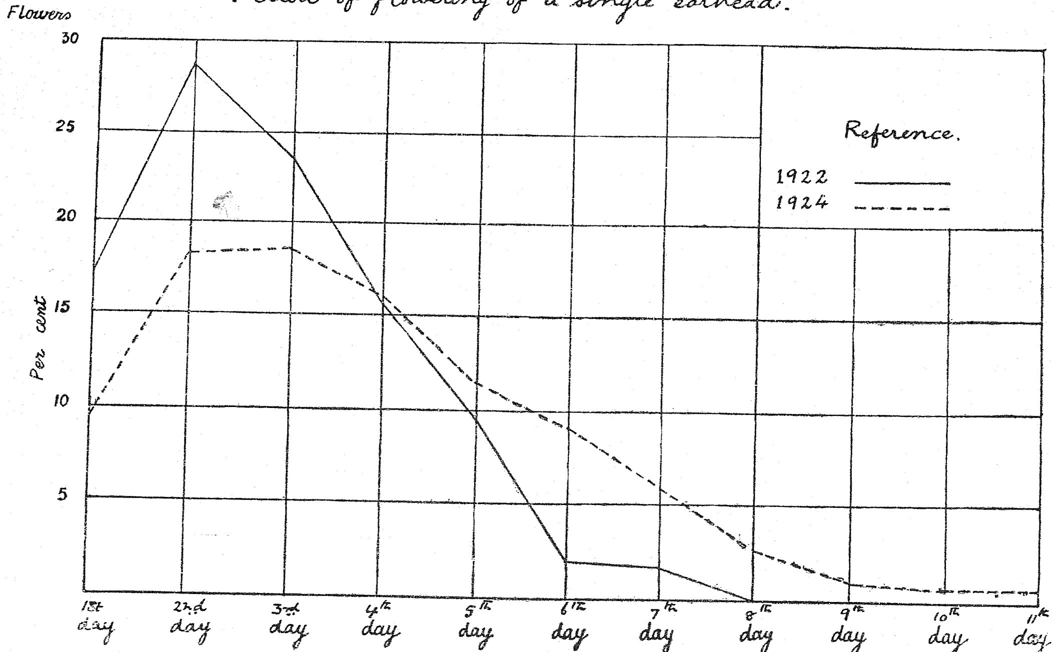


Fig. 3.

open their glumes and are fertilised, but fail to set or mature grain. These are the chief factors in sterility in the earhead and may be called "*aborted*" spikelets.

The relative importance of these types of sterility in a normal season may be indicated by the number found in ten earheads of the *Kangni* variety in 1925. These were as follows :—

Type of sterile spikelets	Number in 10 ears	Mean number per earhead	Proportion of total spikelets
			Per cent.
"Rudimentary" spikelets	118	11·9	5·8
"Abnormal" spikelets	32	3·2	1·7
"Cleistogamic" spikelets . . .	96	9·6	4·8
"Aborted" spikelets	215	21·5	10·6
Fertile spikelets	1559	155·9	77·1

"*Rudimentary*" and "*Abnormal*" spikelets are only noted in the field and they soon drop. Counts taken for sterility in the laboratory, therefore, exclude these.

In 1924, a similar series of counts taken in the field with ten earheads of each of twenty-three varieties, gave the following mean figures.

		Per cent.
1.	"Rudimentary" spikelets	0·2
2.	"Abnormal" spikelets	0·8
3.	"Cleistogamic" spikelets.	4·8
4.	"Aborted" spikelets	18·5
5.	Fertile spikelets	75·7

From these figures it will be seen that aborted spikelets are the chief source of the sterility observed in the field. These spikelets are found to contain undeveloped grain; many of them contain double grains both of which are shrivelled.

The number of sterile grains found after harvest in the various Sind varieties grown side by side at Larkana in 1923 and 1924 has been determined. This excludes, of course, the "rudimentary" and "abnormal" spikelets referred to above, as these can only be determined during the growth of the plants. The figures given

below, however, indicate the proportion of the total spikelets remaining on the head after harvest which do not contain grain.

I. Varieties with low sterility percentage.

—	1923	1924
	Per cent.	Per cent.
Parsad	5·8	did not mature.
Torh	6·8	4·2
Dadkani	8·0	..
Kangani	9·7	6·2
Pista	6·6	did not mature.
Motiaro	7·0	4·7
Sada Gulab	8·6	..
Kolamba Strain 79	10·1	7·8

II. Varieties with medium sterility percentage.

—	1923	1924
	Per cent.	Per cent.
Sighro	11·1	18·8
Jajai	12·9	19·6
Kungro	13·3	17·6
Bidri	14·3	19·0
Sonahari	17·0	20·8
Red Kangro	11·8	15·0
Prong	13·6	15·5
Kolumba Strain 42	14·2	16·2
Ganjro	15·3	18·0
Sathri	17·1	24·3

III. Varieties with high sterility percentage.

—	1923	1924
	Per cent.	Per cent.
Ratrya	22·7	..
Lari	30·3	26·9
Ganja	34·1	25·4
Jirashahi	30·0	Did not mature.

It will be noted that sterility seems to be a varietal characteristic, but that, particularly with the varieties of medium sterility, the difference from year to year is very great. This is illustrated by the more long continued observations on collections of reaped earheads after harvest of the three varieties which have been specially studied, namely, *Kangni*, *Jajai* and *Prong*. These have the following percentages in five successive years, the figures given being the mean of all strains.

Sterility percentage.

—	*Kangni*	*Jajai*	*Prong*
	Per cent.	Per cent.	Per cent.
1921	15·9	25·7	20·4
1922	9·1	17·3	12·1
1923	9·7	12·9	13·6
1924	13·4	21·6	15·8
1925	16·7	17·1	20·8
1926	11·1	20·3	23·1
AVERAGE	12·6	19·6	17·6

The cause of these large variations is not yet clear, yet it may be noted that the inundation, and hence the watering, in 1922 and 1923 was favourable, and in these years the sterility was low. The year 1921 was one of heavy inundation. In 1924 and 1926 the supply of water was late, but it lasted to the end of the season. The year 1925 was the most unfavourable of the series, for the inundation was not only late but only lasted for a very limited time. Much of the crop in the District was a failure.

In selected pure strains from the above three varieties (*Kangni*, *Jajai*, and *Prong*) there was found to be a considerable difference in percentage of sterility, most marked, however in years of high sterility. The following figures illustrate this :—

Variety and strain		Sterility percentage			
		1923	1924	1925	1926
Kangni	No. 27	8·7	12·5	20·9	10·1
	No. 43	9·2	9·8	12·6	12·1
Jajai	No. 77	8·3	21·2	19·1	19·3
	No. 43	9·6	21·6	15·2	21·2
Prong	No. 36	6·9	16·2	19·9	23·0
	No. 57	10·0	12·7	21·7	23·2

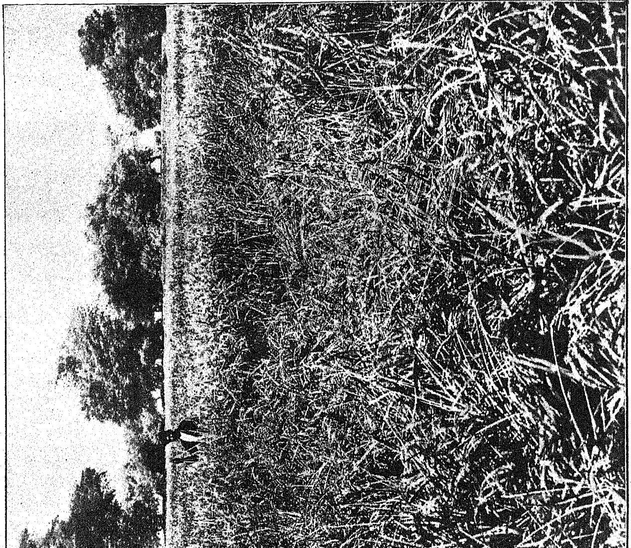
All attempts so far have not enabled these differences between varieties, or between the same variety in different years, to be connected with either insect or fungus attack. Further investigation in this direction is proceeding, but, in the meantime, the evidence regarding possible correlation between the amount of sterility and weather, water or soil conditions may be considered.

Effect of weather conditions. The records of the past eleven years show that excessive sterility (*khas*) has been complained of at Larkana in six seasons, and these seasons were all years in which westerly winds occurred at the time of flowering of the late varieties. For instance, in 1924 these winds occurred when the *Jajai* variety was in full bloom. On examination of the stigmatic surfaces in this variety, they appeared very dry, and after excessive sterility was first noticed, this condition increased in a marked degree.

The forenoon temperatures during the flowering hours seem to have some effect on the setting of grain. Thus the morning temperatures in September in the year 1924 were much lower than in the preceding two years, and the sterility was also much greater in that year. It may be noted here that in Italy, where *brusone* or sterility is a serious matter, Averna-Sacca (19) has found evidence that it is primarily due to sudden and repeated changes of temperature.

Effect of water conditions. Late varieties for which the water partially fails in the latter part of the season show a very high percentage of sterility. For instance, the *Jirashahi* variety in a favourable inundation season, showed a sterility percentage (determined on the dried earheads) of 30 : in a year when the late water failed, it gave a sterility percentage of 85. Similarly a late variety from Bengal gave 25 per cent. and 57 per cent. of sterility respectively under conditions of normal watering

PLATE III.



Plot of *Kangni* Rice No. 27, Larkana, 1925.

and failure of the late watering. Under the latter conditions, the dryness of the stigmatic surface is very marked.

In years of very high floods, sterility has also been found to be considerable. Under very moist atmospheric conditions, it has been noticed that the pollen grains are liable to burst prematurely, and this may, in part, be the cause of the effect noticed in years of high flooding.

Effect of soil conditions. In highly manured soils, it is well known that rice may not flower, but simply form excessive vegetative growth. In one instance, it was noticed in addition that the few earheads formed under these conditions had a high percentage of sterility. On the other hand, in very poor soils where the growth is stunted and the earheads small, the percentage of sterility is high.

Effect of other conditions. Earheads which are covered with muslin bags, in breeding work, always have a much larger percentage of sterility than earheads formed in the open in the same plot. Thus, in three selected varieties, the following figures were obtained from a consideration of over five hundred heads in each case.

Sterility.

—	In open earheads per cent.	In covered earheads per cent.	Increase due to covering per cent.
Kangni	7·5	25·4	17·9
Jajai	12·8	44·0	31·2
Prong	14·4	63·5	49·1

This will, in a small measure, probably be due to the prevention of cross-fertilisation, but it is obvious that other causes are at work which have not yet been entirely ascertained.

VII. Selection and breeding in Sind rices.

Work on improvement of Sind rices has now continued since the year 1922. It was necessary in the first instance to obtain pure strains of several of the most valuable and widely used varieties and for this purpose attention has been concentrated on three of them. These are :—

(*a*) *Kangni.* An early prolific variety, giving a grain of medium, rather coarse quality, which is suited for cultivation on high lands, and which is used for export after parboiling. The bulk of the crop in the Larkana District is of this type.

(*b*) *Jajai.* A variety later than *Kangni*, but still moderately early. It is not prolific, but has fine and scented grain. It needs good soil on a fairly high level.

(c) *Prong.* A late prolific, variety, giving a fine and scented grain, not however equal to *Jajai* in quality. It requires low lying soil.

The actual technique adopted in the work to be recorded was as follows :—

(1) *Nursery.* A fortnight before transplanting, the seed is sown in seed beds ten feet square which are either, manured with sulphate of ammonia, or treated by the "*rab*" method. The seeds are sown in rows, placed one inch apart each way, using a perforated cardboard for the purpose. The seeds are not buried, but merely covered with ashes. Water is applied with a spray till the seedlings have rooted themselves, after which irrigation water is allowed to flow into the beds.

(2) *Transplanting.* This is best done in June, but when the river inundation is late it may be delayed by a month or even more. Single seedlings are transplanted nine inches apart in rows, which are themselves twelve inches apart. This spacing has been found enough for normal development and gives room for working without injury to the plants. The rows as a rule, run at right angles to the water channels, and are about one hundred feet long. The border rows are rejected in any determination of the yield. The plots used are usually one fortieth of an acre and are replicated several times.

When three replications are taken, the probable error in the yield of selected strains of each of the three varieties studied was as follows in 1923 :—

Kangni. From 3·1 to 12·3 per cent. Mean 6·2 per cent.
Jajai. From 1·8 to 9·0 per cent. Mean 5·8 per cent.
Prong. From 5·0 to 14·2 per cent. Mean 8·0 per cent.

In 1924, seven or eight replications were taken of each strain and then the probable error of the yield figures was as follows :—

Kangni. From 2·4 to 3·4 per cent. Mean 2·9 per cent.
Jajai. From 0·7 to 3·1 per cent. Mean 2·2 per cent.
Prong. From 1·9 to 4·5 per cent. Mean 3·5 per cent.

The extent to which selection can profitably be applied to maintain valuable characteristics of a plant is determined by the extent to which the characteristics result from innate and hence hereditary, causes, and to what extent they are modified or determined by the environment. It is first necessary, therefore, to take the seed of each pure strain, or at any rate of one pure strain in each variety, and see how the characters vary from plant to plant in pedigree culture. This has been done, in 1925-26, for one strain of *kangni* (No. 27), one of the *Jajai* (No. 77), and one of *Prong* (No. 36) and the following tables show the variation which occurs, under these circumstances, in the several characters.

TABLE XII.

Statistical constants for Kangni rice, Strain 27.

Characters	Mean value	Modal value	Coefficient of variation per cent.
1. Days up to flowering	78·6 days	78—79 days	2·61
2. Days up to ripening	101·7 days	101—102 days	1·39
3. Length of 20 husked grains	13·7 cm.	13·8—14·0 cm.	3·47
4. Breadth of 20 husked grains	4·5 cm.	4·5— 4·7 cm.	5·30
5. Number of grains per gram of paddy	41·1	40·0—43·9	4·60
6. Percentage of husk in paddy	19·8 per cent.	18·1—21·0 per cent.	15·60
7. Number of spikelets per earhead	146·3	119—139	17·10
8. Number of fertile spikelets per earhead	115·4	104—120	19·4
9. Percentage of sterile spikelets per earhead	20·9	20—30	46·4
10. Number of tillers per plant (paddy)	19·4	16—22	32·2
11. Yield (paddy) of single plant in grams	41·0 grm.	35—45	37·9

TABLE XIII.

Statistical constants for Jajai rice, Strain 77.

Characters	Mean value	Modal value	Coefficient of variation per cent.
1. Days up to flowering	85·1	84—87	2·3
2. Days up to ripening	116·2	115—116	1·3
3. Length of 20 husked grains in centimetre	12·9	12·6—12·8	4·3
4. Breadth of 20 husked grains in centimetre	41	3·9— 4·1	8·3
5. Number of grains per gram of paddy	50	46—50	5·5
6. Percentage of husk in paddy	19·2	17—20	20·9
7. Number of spikelets per earhead	147·4	122—155	21·8
8. Number of fertile spikelets per earhead	114·8	97—134	31·5
9. Percentage of sterile spikelets per earhead	21·1	3·1—25·2	59·3
10. Number of tillers per plant	20·3	18 —25	43·9
11. Yield (Paddy) of single plant in grams	38·6	33—41	44·6

TABLE XIV.

Statistical constants for Prong rice, Strain 36.

Characters	Mean value	Modal value	Coefficient of variation per cent.
1. Days up to flowering	91·4	89—94	3·16
2. Days up to ripening	122·1	121—123	2·10
3. Length of 20 husked grains in cm.	14·3	14·5—14·7	2·7
4. Breadth of 20 husked grains in cm. . . .	4·2	4·2	3·8
5. Number of grains per gram of paddy . .	40·3	39—43	7·4
6. Percentage of husk in paddy	20·4	19—22	19·1
7. Number of spikelets per earhead . . .	109·6	111—136	28·3
8. Number of fertile spikelets per earhead . .	89·2	72—97	27·9
9. Percentage of sterile spikelets per earhead .	19·9	10—20	58·7
10. Number of tillers per plant	20·1	19—26	43·2
11. Yield of single plant in grm.	36·1	28—38	46·4

The results obtained in each of the pure strains examined, though belonging to three different varieties, indicate that the period of growth, size of grain and weight of grain are fairly constant when the plants are grown together. The other characters are subject to very great variation, and depend very much on the particular environment of each plant.

But apart from these variations between plants of the same strain in pedigree culture, it has long been evident that each variety consists of a large number of strains of very different value. Attention was called to apparent changes in the character of the crop grown on the same field by Ishaq (11) and his observations can be easily explained by the originally mixed character of the variety which has been evident throughout the present investigation. In 1921 before the writer took over the control of these investigations one hundred heads had been selected in each of the three varieties under study, and these were grown in line culture in 1922. A number of the lines so obtained were rejected as weak or late, and the rest were harvested. The yielding capacity of the strains varied greatly, and the thirty

best yielders were kept for the further trial. The actual variation in yield per plant in each variety was as follows :—

TABLE XV.

Variation of yield in strains of rice varieties.

Variety	Number of strains	Highest and lowest yield per plant	Average yield per plant
		grm.	grm.
Kangni	89	1·4 to 5·1	2·4
Jajai	61	1·3 to 4·5	2·0
Prong	88	1·4 to 5·9	2·8

In the following year the thirty selected strains were sorted out, and finally only five of the strains of each variety were kept for study and multiplication. These were found to retain their high yielding character from generation to generation, but were still further reduced for convenience of multiplication in 1925 to three strains of *Kangni* (Nos. 27, 43 and 25), two strains of *Jajai* (Nos. 77 and 43) and two strains of *Prong* (Nos. 36 and 57). Tested in six or seven replications in that year (1925) and compared with the crop from unselected seed of the same variety, the following results were obtained.

TABLE XVI.

Increase of yield in selected strains of rice.

Variety	*strain*	Increased yield over unselected seed	Remarks
		Per cent.	
Kangni	No. 27	19·1	All replications (6) agreed.
	No. 43	28·2	„ „ (7) „
	No. 25	31·7	„ „ (6) „
Jajai	No. 77	14·0	Six out of seven replications agreed.
	No. 43	27·4	Five out of seven replications agreed.
Prong	No. 36	32·2	All replications (6) agreed.
	No. 51	24·9	„ „ (7) „

The actual yields per acre obtained from these strains in three successive years in field scale trials may be of interest.

TABLE XVII.

Yield of selected strains of rice per acre.

—		1924	1925	1926	Maximum
		lb.	lb.	lb.	lb.
Kangni	No. 27	1,200	1,483	1,370	2,422
	No. 43	1,672	1,488	1,406	1,622
Jajai	No. 77	1,526	1,421	1,285	1,660
	No. 43	..	1,648	1,703	1,976
Prong	No. 36	1,288	1,575	1,406	1,628
	No. 51	1,320	1,320	1,012	1,320

The strains described have retained their special yielding character when grown on a large scale by farmers, and they are now established in cultivation.

The selected strains of each variety, having been selected for yield, do not show any large difference in time of ripening among themselves.

VIII. Acclimatisation of exotic rices.

While all the effects at improvement of rices for cultivation in Sind have concentrated on selection from the best of the local types, and especially on those suitable for cultivation in Upper Sind, the possibility of obtaining from abroad or from the other parts of India types of rice which could replace some of those now grown has not been neglected. In the course of this inquiry, an apparently indigenous type of rice, named *Bengalo* was discovered in cultivation, whose name proclaims its ultimate derivation from Bengal which is of some interest in this connection, as showing how some, at least of exotic rices, have already acclimatised themselves.

This *Bengalo* rice was found in cultivation at Tando Ghulam Hyder in Lower Sind, and proved to be the best type in Sind for quality, having a long fine grain and a thin shell and tight husk. It is also highly scented, and has been valued at a higher price in the market than the *Jajai-Sugdasi,* which has the highest reputation among the scented Sind varieties. It ripens along with the latter, and in 1926 has given (in six replications) six per cent. higher yield. The existence of such a type has been hitherto unsuspected, but it indicates the possibilities of acclimatisation even under conditions so widely different as Bengal and Sind.

Apart from the above case, the efforts at introducing suitable varieties for Sind from outside have not been very promising, but details regarding them may be given.

Japan rices. Seeds of the following Japan varieties have been tried under Upper Sind conditions :—*Aiokoku, Kamino Shiratma, Oba, Myakoe, Okawa-shiragasi, Shiranki, Omachi, Magatma* and *Sekitori.* All of these are dwarf in habit of growth, hardly attaining a height of eighteen inches. Two of the varieties, namely *Kamino* and *Oba* flowered in twenty-eight days after transplanting, but none of them matured grain. They were largely affected by the disease known as *Sclerotial* disease caused by the fungus *Sclerotium oryzae.*

Rices from the Central Provinces (India) :—Nine varieties were tried under Upper Sind conditions, sent under the following names :—*Kariasela, Khuraban, Kanta Saila, Bhadaw-Bhundi, Khoot Bohira, Bhat Mathura, Bhat Gurmatia, Bhat Pundari, Karia-Bohiri.* All of them were coarse grained, and have no characters which make them specially suitable for Sind.

Assam rices. No less than sixteen varieties from Assam were grown in Upper Sind. Most of them were high tillering and three of the varieties were specially interesting in this respect. These were (1) *Basmati,* (2) *Basant Bahar* (A. S. 224) (3) *Tipidumia Basant Bahar* (A. S. 224) is a very fine rice, and this combined with high tillering capacity indicates possible high value. *Tipidumia* is perhaps the most highly tillering rice we have got, though it is early and has a coarse red grain.

Bengal Rices. The following rices from Bengal (Dacca) have been studied in Upper Sind :—*Suraj Mukhi, Katak Tara,* Jasa-*balum, Dudsar, Indrasail, Dadkani.*

The last of these (*Dadkani*) is not a new introduction as it has been grown in Upper Sind for a number of years. It is a late variety and does not appear to be widely adaptable. It has, however, a very fine grain and is popular,—though the grain is not suited for parboiling. It has been compared with *Prong,* and *Jajai* in three successive years, as to time required for maturity and the yield per plant. The tests were made in eight replications in each case.

TABLE XVIII.

Comparative characters of Dadkani and Prong rice in Sind.

—	*Dadkani* Rice	*Prong* (No. 65 or 36 Rice
1. Days needed to mature—	Days	Days
1924	129	134
1925	130	130
1926	123	134
2. Yield per plant—	Grm.	Grm.
1924	21·1	17·0
1925	15·2	14·0
1926	16·3	18·7
AVERAGE	17·5	16·8

TABLE XIX.

Comparative characters of Dadkani and Jajai rice in Sind.

—	*Dadkani* rice	*Jajai* (No. 63 or 77 rice)
1. Days needed to mature—	Days	Days
1924	124	120
1925	124	115
1926	118	123
2. Yield per plant—	Grm.	Grm.
1924	24·1	22·0
1925	18·7	14·0
1926	15·2	17·5
AVERAGE .	19·3	17·8

It will thus be seen that this imported type (*Dadkani*) from Bengal has given at least equal yields at Larkana to those given by the other high quality scented rices of Upper Sind. On continued growth it has, however, been found by growers to be delicate and to be more susceptible to the leaf spot (*Helminthosporium*) disease, which has done so much damage in Upper Sind in recent years, and particularly in 1925.

Out of the other five Bengal rices mentioned above *Suraj Mukhi* and *Katak Tara* proved to be early when grown at Larkana, while the others were extraordinarily late. *Dudsar* ripened twenty six days later than *Jajai*, but gave 59 per cent. higher yield. *Indrasail* ripened fortyone days later than *Jajai*, and gave 16 per cent. lower yield than the latter. These yields were taken in eight replications in 1925. These very late rices are, however, of little use in Sind owing to the failure of the water supply and to the liability to very great cold and even frost in December.

Rices from the Konkan. There have been worked out in recent years at Karjat in the Konkan a number of pure strains of the very valuable fine *Kolamba* rice, and several of these have been tested at Larkana (Upper Sind). These *Kolamba* rices have very small grains, and are valued higher than the local non-scented varieties, though they are not suited for parboiling. Trials with replication show that none of them yields more highly than the local selections from *Kangni* rice, while some of them (*Kolamba* No. 79 in particular) seem to be specially susceptible to the leaf spot (*Helminthosporium*) disease.

APPENDIX I.

List of References.

1. Roy, S. C. Classification of the Wild Rices of the Central Provinces and Berar. *Agri. Jour. India*, XVI, p. 365 (1921).
2. Graham, R. J. D. Preliminary Note on the Classification of Rice in the Central Provinces. *Mem. Dept. Agri. India, Bot. Ser.*, VI, No. 7 (1913).
3. Copeland, E. B. *Rice* (New York 1924).
4. Joshi, K. V., and Gadkari, M. V. Studies in the Rice Plant and on Rice Cultivation. *Bombay Dept. Agri. Bull.* 114 (1924).
5. Jack, H. W. Rice in Malaya. *Malayan Agri. Jour.*, XI, pp. 103, 139, 168 (1923).
6. Jacobsen, H. O. Correlative Characters of the Rice Plant. *Philippine Agri. Rev.*, IX, p. 74 (1916).
7. Howard, A. *Crop Production in India*, (London 1924).
8. Mitra, S. K. and others. Seasonal Variation in Paddy. *Agri. Jour. India*, XIX (1924).
9. Chambliss, C. E., and Jenkins, J. M. Some new varieties of Rice. *U. S. Dept. Agri. Bull.* 1127 (1923).
10. Hiranandani, D. H. Rice Cultivation in Sind. *Poona Agri. Coll. Reprint*, 6 (1916).
11. Ishaq, A. R. Rice Cultivation in the Larkana District, Sind. *Bombay Dept. Agri. Bull.* 99 (1921).
12. Hector, G. P. Notes on Pollination and Cross-fertilization in the common Rice Plant. *Mem. Dept. Agri. India, Bot. Ser.*, VI, p. 1 (1913).
13. Parnell F. R. and others. The Inheritance of Certain Characters in Rice. *Mem. Dept. Agri. India, Bot. Ser.*, IX (1917), p. 75.
14. McKerral, A. Some Problems of Rice Improvement in Burma. *Agri. Jour. India*, VIII (1913), p. 317.
15. Crisostomo, M. Cultural Notes on Upland Rice in the Philipines. *Philipine Agri. and Forester*, III (1915), p. 111.
16. Kemine, M. Blooming of Rice and Associated Phenomena. *Zeitschr. Pflanzen züchtung*, III (1914), p. 339.
17. Ikeno, S. On the Pollination and Crossing of Rice. *Zeitschr. Pflanzeu-züchtung*, II (1914), p. 495.
18. Farneti, R. Sopra il brusone del riso-Atti 1st. *Botan. dell' Univ. di Pavia* XVIII (1921), p. 109.
19. Averna, sacca. *Bruso.,e* of Rice. *Bol. Agr.* (*Sao Paulo*), 13th Series (1912), p. 291.
20. Thompstone, E. and Sawyer, A. M. The *Gwabo* Disease of Paddy. *Burma, Agri. Dept. Bull.* 16, (1920).

APPENDIX II.

Length of earhead and number of branches per earhead in Sind rice varieties, 1923.

Variety	Mean length of earhead in inches	Mean number of earhead branches
Sighro	7·2	7·9
Parsad	7·5	8·6
Lari	7·7	9·6
Ganja	7·7	8·3
Jirashahi	7·6	10·5
Bidri	8·3	9·1
Kunjro	8·3	11·1
Ganjro	8·3	10·2
Red Kangro	8·4	8·6
Torh	8·4	9·3
New Type B.	8·5	8·5
New Type A.	8·5	8·5
Sathri	8·7	11·0
Ratrya	9·0	8·5
Pista	9·3	9·9
Sonahiri	10·0	8·5
New Type Y.	9·1	10·5
Motiaro	10·2	17·6
New Type Z.	10·7	12·2
Sada Gulab	10·7	8·9

APPENDIX III.

Number of spikelets per earhead in Sind rice varieties, 1923.

Variety	Number of earheads examined	Mean Number of spikelets per earhead
Lari	106	92·3
New Type B.	161	94·2
Sighro	205	94·7
Sonahari	180	95·5
Ganja	192	96·6
Ratrya	119	102·5
Prong	480	104·6
Red Kangro	147	106·3
New Type A.	185	109·3
Sada Gulab	147	110·6
Jajai	479	142·3
Torh	193	145·3
Ganjro	..	146·4
Parsad	116	150·0
Sathri	176	158·5
Kangni	448	162·7
Bidri	182	163·9
Motiaro	155	196·1
Pista	144	205·8
Kunjro	179	253·6
Jirashahi	115	303·1

APPENDIX IV.

Yield of single plants (spaced 12 by 9 inches).

Variety	Yield per plant in grm.	Variety	Yield per plant in grm.	Variety	Yield per plant in grm.
Sind rices in 1924.					
1 Torh	38·32	2 New type Y	35·94	3 Motiaro	34·92
4 Kunjro	30·73	5 Sada Gulab	30·61	6 Dadkani	30·16
8 Bengalo	28·80	9 Red Kangro	27·78	10 Early Karjat	26·19
11 Pista	25·28	12 Sonahiri.	25·28	13 Ganjro	25·06
14 Sathri	23·47	15 Ganja	23·36	16 Parsad	22·68
17 New Type Z.	22·22	18 Bidri	21·77	19 Ratrya	20·86
21 New Type X.	20·18	22 Jirashahi	19·73	23 Sindhi Kambroo	18·25
24 Chajrai	18·14	25 Sighro	17·57	26 Lari	17·12
27 New Type A.	17·01	28 New Type B.	16·66	29 Barsati	14·17
30 New Type Za.	13·72	31 Bengal rice	6·57	....	..
Konkan rices, 1925.					
1 Kolumba 241	40·14	2 Kolumba 184	35·60	3 Kolumba 79	24·15
4 Kolumba 153	20·30	5 Kolumba 42	18·82	....	..
Bengal rices, 1925.					
1 Indra Sail	27·55	2 Dudsar	27·32	3 Jeshabalam	23·70
4 Dadkani	22·79	5 Surajmukhi	17·23	6 Katak Tara	11·90
7 Bengal rice	5·10	....	..	....	..
Assam rices, 1925.					
1 Tipidumia	38·44	2 Basmati	33·11	3 Basant Bahar A. S. 234	26·30
4 Nagra Sail	26·08	5 Lati Sail	26·08	6 Kartak Sail	22·79
7 George Sail	22·79	8 Raskadum	21·43	9 Barashmurti	18·81
10 Indra Sail	18·48	11 Tulsi Joha	18·14	12 Sail Badal	17·69
13 Basant Bahar 233	16·78	14 Kasalatha	15·08	15 Bir Pak	6·57
Central Provinces rices, 1925.					
1 Khuraban	32·09	2 Bhat Gurmatia	31·41	3 Bhat Pandri	22·68
4 Karia bohiri	22·68	5 Karia Sela	21·20	6 Kanta Sela	15·08
7 Bhadun bhimdi	14·17	8 Bhat Mathura	7·14	....	..
Deep water Dacca rices, 1925.					
1 Secha Aman	5·21	2 Joyana	4·64	3 Narianda	4·53
Japan rices, 1925.					
1 Shiranki	7·59	2 Omachi	5·32	3 Seki Tori	3·85
4 Shiratama	2·38	5 Kamino	1·92	6 Magatama	1·70
7 Oba	1·02	8 Okwashiragasi	0·90	9 Aiokoku	0·45
10 Myaku	0·34	....	..	....	..

APPENDIX V.

Flowering and ripening periods of foreign varieties of rice as grown in Sind in 1925-26.

Variety	Days to flower from transplanting	Interval from flowering to maturity	Days to ripen from transplanting
Kolamba strains.			
Kolamba 79	69	26	95
" 184	65	32	96
" 153	70	45	115
" 241	84	31	115
" 42	89	34	123
Bengal varieties.			
Katak Tara	68	33	101
Suraj Mukhi	67	34	101
Dadkani	80	40	120
Jeshabalam	100	34	134
Dudsar	95	39	134
Indra Sail	110	32	142
Assam varieties.			
Basant Bahar AS 224	62	27	89
Tipidumia	61	34	95
Kasa Latha	66	36	102
Raskadum	65	37	102
Barashmurti	64	38	102
Tulsi Joha	74	30	104
Basmati	71	41	112
Kartik Sail	88	33	121
Basant Bahar 233	88	34	122
George Sail	83	39	122
Nagra Sail	94	40	134
Lati Sail	98	36	134
Bir Pak	100	38	138
Sail Badal	105	35	140

APPENDIX V—*contd.*

Variety	Days up to flowering	Interval	Days up to harvest
Assam varieties.			
Indra Sail	104	38	142
Badsha bhog	100	48	148
Central Provinces varieties.			
Karia Sela	67	36	103
Khuraban	71	32	103
Kanta Sela (Early)	65	43	108
Bhadun Bhundi	99	12	111
Khut Boira	74	40	114
Bhat Mathura	73	42	115
Bhat gurmatia	74	41	115
Bhat Pandri	79	36	115
Karia bohiri	79	42	121
Deep water Dacca rice.			
Narenda	99	33	132
Secha aman	99	55	154
Joyana	108	46	154
Japan varieties.			
Okwashiragasi	50	46	96
Shiranki	50	46	96
Omachi	48	48	96
Magatma	50	46	96
Seki tori	48	48	96
Aiokoku	48	60	108
Kamino	28	80	108
Shiratma	48	60	108
Oba	35	73	108
Myakoo	48	60	108

APPENDIX VI.

PART I.

Time of the day when opening of flowers takes place.

Variety	Number of flowers opened on one earhead								Unopened and abnormal	Total
	7-30	8-30	9-30	10-30	11-30	12-30	1-30	2-30		
1922.										
1. Kangni . .	0	0	10	46	87	13	0	0	2	158
2. Jajai . .	0	0	9	62	72	13	0	0	5	161
3. Prong . .	0	0	6	46	59	16	0	0	4	131
4. Sathri . .	0	0	7	21	73	20	0	0	2	123
5. Sighro . .	0	0	9	46	29	4	0	0	2	90
6. Sonahiri .	0	0	4	63	51	17	0	0	3	138
7. Sada Gulab .	0	0	0	34	57	24	0	0	3	118
8. Torh . .	0	0	2	33	104	21	0	0	4	164
9. Ganjro . .	0	2	0	10	54	7	0	0	2	75
10. Bidri . .	0	1	6	30	40	6	0	0	1	92
TOTAL .	0	3	53	399	626	141	0	0	28	1,250
PERCENTAGE .	0	0·24	4·24	31·92	50·08	11·28	0	0	2·24	100
1924.										
1. Dadkani .	0·1	1·9	6·1	9·6	36·6	37·4	15·1	6·5	9·0	119·6
2. Motiaro . .	0	1·4	5·2	6·7	3·2	5·7	11·3	1·3	47·4	82·2
3. Lari . .	0	0·1	2·8	4·0	16·3	49·2	39·2	19·4	3·3	134·3
4. Ganja . .	0	1·2	5·8	5·8	14·2	38·3	35·5	35·6	5·8	142·2
5. Kangni . .	0	0·5	1·5	3·5	9·9	33·5	36·5	20·3	6·1	111·8
6. Kunjro . .	0	0·4	4·7	8·6	27·7	72·4	28·9	4·1	3·7	150·5
7. Koluba 42 .	0	0	4·3	13·0	30·9	63·6	48·5	16·7	13·5	190·5
8. Pista . .	0	0	6·0	20·1	43·1	73·3	36·2	9·8	11·6	200·1
9. Jirashahi .	0	0	11·2	30·1	45·2	73·0	85·5	47·3	10·3	301·6
10. Bengal rice .	0	0·1	5·3	13·9	17·6	27·0	36·8	19·4	5·5	125·6
11. Sighro . .	0·5	8·7	5·6	9·8	43·2	67·3	11·1	0	5·2	151·4
12. Bidri . .	2·7	5·2	8·1	21·0	56·8	39·5	3·0	0	4·8	141·9
13. Ganjro . .	0·3	0·6	5·1	6·5	30·6	51·5	7·1	0	5·7	107·4
14. Sathri . .	2·2	7·2	12·5	19·4	42·0	9·9	1·3	0	8·3	102·8
15. New type A. .	18	16·6	13·2	19·9	34·0	11·6	1·1	0	4·3	118·7
16. Red Kangro .	11·0	10·4	15·8	19·0	22·9	10·1	1·1	0	3·2	93·5
17. Kolumba 79 .	5·7	12·2	23·4	39·8	94·0	81·0	18·0	0	28·3	302·4
18. Parsad . .	28·3	29·6	28·1	13·3	17·7	25·2	11·1	0	11·6	167·0
19. Sonahiri .	2·6	2·6	5·0	15·9	38·6	44·1	12·5	0	11·1	132·4
20. Sada Gulab .	4·3	9·6	10·8	14·9	16·4	25·0	22·4	0	0	103·4
21. Torh . .	2·5	6·2	11·3	12·8	12·5	21·6	19·1	0	0	86·0
22. Prong . .	0·5	1·1	8·2	15·2	18·1	18·0	9·5	0	7·7	87·3
23. Jajai . .	2·1	2·3	8·8	10·3	17·6	24·8	17·5	0	0	83·4
TOTAL .	80·8	117·8	209·6	332·5	689·1	902·0	508·3	180·4	206·4	3,226·0
PERCENTAGE .	2·5	3·7	6·6	10·0	21·5	27·8	15·9	5·6	6·5	100

APPENDIX VI—*contd.*

PART II.

Period of flowering of a single earhead.

Variety	NUMBER OF FLOWERS OPENED ON EACH DAY								Unopened and abnormal	TOTAL
	1st	2nd	3rd	4th	5th	6th	7th	8th		
1922.										
1. Kangni . .	20	54	51	25	6	0	0	0	2	158
2. Jajai . .	37	54	26	28	11	0	0	0	5	161
3. Sathri . .	28	36	28	21	8	0	0	0	2	123
4. Sighro . .	29	39	9	9	2	0	0	0	2	90
5. Ganjro . .	18	16	22	13	4	0	0	0	2	75
6. Bidri . .	11	33	28	16	3	0	0	0	1	92
7. Prong . .	13	29	32	20	20	5	8	0	4	131
8. Sonahiri .	26	28	30	20	20	7	4	0	3	138
9. Sada Gulab .	11	36	36	11	11	6	4	0	3	118
10. Torh . .	21	33	32	32	32	6	4	0	4	164
TOTAL .	214	358	294	195	117	24	20	0	28	1,250
PERCENTAGE .	17·12	28·64	23·52	15·60	9·36	1·92	1·60	0	2·24	100
1924 Early varieties.										
1. New Type A. .	14·5	29·0	32·0	25·5	13·4	0	0	0	4·3	118·7
2. Sighro . .	17·7	40·3	27·9	30·5	10·3	19·5	0	0	5·2	151·4
3. Bidri . .	18·6	49·4	33·1	25·4	9·6	1·0	0	0	4·8	141·9
4. Ganjro . .	20·1	34·8	22·3	13·0	10·8	0·7	0	0	5·7	107·4
5. Sathri . .	25·3	30·4	23·3	9·0	6·3	0·2	0	0	8·3	102·8
6. Red Kangro .	25·3	34·2	19·5	9·0	1·9	0·4	0	0	3·2	93·5
7. Pista . .	10·3	15·9	20·9	44·8	36·6	39·3	20·7	0	11·6	200·1
8. Kolumba strain 79.	10·1	59·7	70·2	64·6	43·1	16·6	5·4	4·4	28·3	302·4
9. Parsad . .	14·0	31·7	40·1	34·7	8·3	11·2	3·6	2·8	11·6	167·0
10. Sonahiri .	10·9	25·5	26·2	18·6	15·9	12·3	7·8	4·1	11·1	132·4
11. Jajai . .	8·2	20·9	18·2	12·4	7·6	8·2	6·1	1·8	0	83·4
12. Jirashahi .	26·7	41·2	40·5	38·1	48·0	45·5	44·5	6·8	10·3	301·6
13. Kolumba strain 42.	8·3	14·7	37·7	32·7	37·8	32·7	12·4	0·7	13·5	190·5

APPENDIX VI—*concld.*

PART II—*concld.*

Period of flowering of a single earhead.

Variety	Number of flowers opened on each day											Unopened and abnormal	Total
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th		
1924 Late varieties.													
14. Sada Gulab	12·0	20·6	20·4	11·4	10·1	15·3	7·5	3·6	2·5	0	0	0	103·4
15. Torh	13·8	18·7	12·8	10·7	9·7	12·2	4·5	3·1	0·5	0	0	0	68·0
16. Motiaro	5·5	7·2	11·4	3·3	2·9	2·1	0·7	1·2	0·5	0	0	47·4	82·2
17. Dadkani	4·6	12·6	12·6	20·8	19·3	13·7	18·4	5·9	1·7	0	0	9·0	119·6
18. Kunjro	11·7	27·5	36·6	33·9	12·3	12·3	9·3	3·1	0·1	0	0	3·7	150·5
19. Prong	6·5	21·9	2·7	9·7	7·7	9·6	6·2	5·4	0·5	0·4	0	7·7	78·3
20. Kangni	19·9	17·1	21·7	13·9	11·1	4·2	3·8	4·3	8·7	1·0	0	6·1	111·8
21. Lari	6·0	9·3	19·1	21·8	24·0	15·8	13·6	7·2	7·2	3·5	3·5	3·3	134·3
22. Ganja	8·0	18·9	20·0	22·7	18·3	12·4	9·4	5·5	4·6	10	6·6	5·8	142·2
23. Bengal Rice	7·0	7·8	16·7	14·5	6·4	11·2	16·4	19·1	2·8	7·2	11	5·5	125·6
TOTAL	305·0	589·3	594·9	520·9	371·4	298·5	190·3	79·0	30·1	22·1	21·1	208·4	3,229
PERCENTAGE	9·5	18·2	18·4	16·1	11·5	9·2	5·9	2·5	·9	·7	·7	6·4	100

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CONTENTS

VARIABILITY IN CERTAIN ECONOMIC CHARACTERS, PARTICULARLY IN SEED WEIGHT AND WEIGHT OF LINT PER SEED, IN PURE STRAINS OF BROACH DESHI COTTON.

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I. General considerations.

The senior author's former Memoirs on Gujarat cotton [1] have described the isolation and the characters of some of the more important and characteristic strains of three of the principal varieties of *Gossypium herbaceum* cultivated in Gujarat and also discussed the heredity of certain important characters of these cottons. The present paper deals with certain aspects of the variability of economic characters and particularly seed-weight and lint-weight per seed, within pure strains of *Broach-deshi* cotton, whether in relation to the season of growth, to the rapidity of ripening, to the position of the plant on which the bolls are formed, or to certain other environmental factors. The matter is important, because the relationship of the seed-weight to the lint-weight is essentially the *ginning percentage*, one of the most important factors in determining the value of a type of cotton for cultivation. This ginning percentage, or the percentage of the weight of lint on the seeds, to the whole weight of the lint and seeds together (*i.e.*, the weight of the seed-cotton) is almost obviously, a composite factor, and the present study is an attempt to reduce to simpler terms the conception, and to relate its variations to the elements of which these are composed, namely, the variations of the seed-weight and the lint-weight. By using pure strains, maintained in pure line for several generations, the effect of hereditary variations can be eliminated, and that of environmental conditions separately considered.

It has been stated above that the ginning percentage is almost certainly a composite factor. As determined in practice, it is not only composite but is, as a rule, very inaccurate as usually given, for the figure generally obtained for any type of cotton is secured by actually ginning a known weight of seed-cotton (*kapas*) and measuring the lint obtained, or in small samples, by weighing seed and lint separately.

[1] *Mem. Dept. Agri. India Bot. Ser.*, Vol. XI, No. 4; XII, No. 5; and XIV, No. 2.

The figure thus secured is affected by certain factors of which account is not by any means always taken. Three of these neglected factors may be here mentioned.

The first inaccuracy is caused by the presence of extraneous material in the seed-cotton, of which the most common consists of broken up dried leaves and fragments of broken bolls. Most of this will appear in the lint, and hence will tend to give a high value to the proportion of lint, or in other words, to the ginning percentage. Most figures given as the result of field trials are somewhat high on this account. It can be avoided, however, if sufficient care is taken in picking.

The second and most important inaccuracy results from the presence of seeds damaged by bollworms, which are liable to be crushed or broken up during ginning. This will also tend to give a high figure for the ginning percentage, as some bits from the crushed seed will almost inevitably get into the lint. Further, any attack of this sort on the seed will almost certainly tend to lighten it, and so again give too high a figure for the ginning percentage. In the case of attack by the spotted bollworm (*Earias* sp.) it can be avoided, as bolls attacked by this pest can always be detected. But where the damage is caused by the pink bollworm (*Gelechia gossypiella*), as no outward sign is visible unless each cell of every boll is carefully examined after spreading out the seed-cotton (*kapas*), it is much more difficult to eliminate.

The third inaccuracy is still more universal, and more difficult to avoid. It is caused by the presence of so-called *specks* in the lint. These consist either of ovules unfertilized but sometimes developing very short hairs, or are caused by the presence of dead and undeveloped seeds. Both of these types of specks often pass off in the lint after being crushed, and so increase the ginning percentage of a type of cotton or of the cotton from a series of plants. The extent to which this last factor influences the recorded ginning percentage, and the recorded lint index (weight of lint per one hundred seeds in grammes) in the produce of a series of pure strains of *Broach-deshi* cotton is shown in the following Table.

TABLE I.

Effect of removal of specks in decreasing ginning percentage and lint index in the produce of a single plant.

Strain	Decrease of ginning percentage		Decrease of lint index	
	Least	Greatest	Least	Greatest
	Per cent.	Per cent.	Grm.	Grm.
1. 1027 A. L. F.	0·04	0·88	0·01	0·26
2. B.-1	0·02	2·65	0·01	1·07
3. I-A Long Boll	0·00	0·61	0·00	0·61
4. Selection II (Surat)	0·07	1·08	0·00	0·38
5. Selection II (Broach)	0·12	0·62	0·03	0·07
6. I-A Cylindrical Boll	0·07	0·46	0·01	0·08

The effect is very variable, as will be seen. Usually it will not be serious, but it may be very important as in the case of strain B-I or of Selection II grown at Surat.

Apart from these inaccuracies, the ginning percentage is composite, as it is really the ratio of two factors, each of which may vary independently of the other. These two factors are the weight of the seed and the weight of the lint on the seed. In some cases, as for instance in the types studied by Kottur [1] in crossing a strain of *Gossypium neglectum* with a strain of *Gossypium herbaceum* where the seed-weight is similar in both the parents, the ginning percentage may be taken as a single factor. But this will by no means always be the case, though one of the authors [2] has shown in a previous Memoir that there is a significant but not very close correlation between the weight of seed and lint in his pure strains of *Broach-deshi* cotton. It is obvious; therefore, that the variability of these two factors, and their correlations under varying conditions of occurrence and environment must be separately studied before we consider the ginning percentage as a figure which may be used with confidence as characteristic of a strain of cotton.

This is all the clearer when it is considered that the weight of lint per cotton seed (lint index) is itself a composite, depending on the number of hairs per seed, multiplied by the weight per hair. This last may alter with a change either in the length or in the thickness of each hair.

In the present paper the authors have, therefore, considered first the variation of the seed and lint-weight per seed separately as occurring in pure strains grown side by side.

II. Variability in seed-weight and in lint-weight per seed.

The strains which have been used in these investigations are those of *Broach-deshi*, cotton described by one of the authors in his former Memoirs (loc. cit.). Their characteristic features may be summarised as follows :—

(1) *B-I.* This type is retained as earlier ripening than any other strain, owing to the production of a large number of flower-buds in proportion to the vegetative growth of the axillary vegetative branches and the monopodia. It has an average ginning percentage and seed-weight.

(2) *C-1.* This type is the least bushy, has an exceptionally open habit of growth, and is hence less attacked by bollworm, and as a result has a larger percentage of success in flower-buds, and of bolls from flowers, than is obtained in other strains, but the ginning percentage is about the normal for *Broach-deshi* cotton.

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[1] *Mem. Dept. Agri. India, Bot. Ser.*, XII, No. 3.
[2] *Mem. Dept. Agri. India, Bot. Ser.*, XIII, No. 5

(3) *I-A Cylindrical Boll.* This is the bushiest strain of all the selected types, has a large heavy seed, but a high ginning percentage. Its value lies in its high yield, high ginning percentage and good staple.

(4) *I-A Long Boll.* The *general* character of the plants in this strain is very similar to that in the last named, and the weight of the seed is about the same. It has a high ginning percentage, and is specially valuable on this account, and also because of its drought resistance. It is less variable in length of staple and ginning percentage of lint than other strains.

(5) *Selection II.* The plants of this strain are of a bushy character. The weight of the seed is almost similar to the last mentioned type, and the ginning percentage is high. It is retained in the collection on account of the spreading character of the bracts in the flower-bud stage, which leads to less attack by bollworm in that stage.

(6) *1027 A. L. F.* This is the best staple strain. The plants are bushy, the seeds are heavy, while the ginning percentage is somewhat low, though higher than the average of the strains hitherto cultivated. It is now grown annually on a large scale, several hundred thousand acres being under this type.

Two additional pure strains have been used in the present series of observation as follows :—

(7) *B. D. 6.* This was selected in 1920-21 for its wilt-resisting character, but in other respects it is normal to the *Broach-deshi* cotton.

(8) *B. D. 4.* This strain has the heaviest seed among the known types of *Broach-deshi*, and is highly susceptible to wilt.

Both of these new strains have been propagated from protected flowers and are pure since 1922-23.

All these eight strains of *Broach deshi* cotton have been grown in pure line for several years, and the opportunity was first taken to see what is the variability of the seed-weight and the lint-weight per seed from plant to plant of each strain in one season, and how this variability is affected when a known mixture of two or more of these are grown together.

(*a*) Variability in seed-weight and lint-weight from plant to plant in pure strains and in a mixture of strains.

The tests were made with the average of all the bolls of each plant, 25 plants of each type being taken in 1923-24, and 50 plants of each type in 1924-25. These were grown in each case on a single plot. The following Table shows the co-efficient of variability from plant to plant in each strain.

TABLE II.

Variability from plant to plant of seed-weight and lint-weight per seed with pure strains.

Strain	Coefficient of variability			
	1923-24		1924-25	
	Seed-weight	Lint-weight	Seed-weight	Lint-weight
	Per cent.	Per cent.	Per cent.	Per cent.
B.-1	4·4±0·45	5·8±0·55	..	..
I-A Long Boll	4·7±0·44	5·0±0·55	..	..
Selection II (Surat)	4·6±0·43	6·5±0·62	8·0±0·53	11·6±0·76
Selection II (Broach)	..	..	8·2±1·15	10·1±1·39
1027 A. L. F.	7·5±0·71	8·2±0·77	6·9±0·46	9·6±0·64
I-A Cylindrical Boll (Broach)	..	..	5·7±0·75	6·7±0·89
B. D. 4 (Broach)	..	..	3·4±0·45	5·8±0·76
B. D. 6 (Broach)	..	..	5·6±0·80	9·3±1·30

These figures show that the variability of both seed weight and weight of lint per seed is greater in some years than others. It has been suggested that the higher variability in 1924-25 is connected with a cold wave which occurred during the ripening of the bolls, but there is no evidence as to whether this was the cause or no. On the whole, the weight of lint per seed seems more variable from plant to plant than that of the seed itself.

When a mixture of seeds of the different strains were grown together the variability at once increased, as would be expected, and the following table from lines of plants of such mixtures are interesting as showing one source of the great variability of the seed-weight and lint-weight per seed in an ordinary crop composed of many strains. The number of plants of each strain in the following mixture was the same.

TABLE III.

Variability from plant to plant of seed-weight and lint-weight per seed with mixtures of strains.

Strain mixture	Coefficient of variability			
	1923-24		1924-25	
	Seed-weight	Lint-weight	Seed-weight	Lint-weight
	Per cent.	Per cent.	Per cent.	Per cent.
B.-1 & 1027 A. L. F.	$15·0 \pm 1·01$	$14·3 \pm 0·96$	..	..
Selection II & 1027 A. L. F.	$10·1 \pm 0·68$	$9·2 \pm 0·62$	$11·7 \pm 0·55$	$14·4 \pm 0·68$
B. D. 6 & B. D. 4	..	..	$16·7 \pm 1·62$	$17·8 \pm 1·73$
Selection II & B. D. 4	..	..	$15·3 \pm 1·45$	$15·5 \pm 1·54$
Selection II & I-A Cylindrical Boll	..	..	$8·6 \pm 0·82$	$15·9 \pm 1·52$
I-A Cylindrical Boll & B. D. 6	..	..	$14·9 \pm 1·45$	$18·1 \pm 1·76$
B.-1, I-A Long Boll and Selection II	$11·3 \pm 0·54$	$14·4 \pm 0·68$	..	..
B.-1, I-A Long Boll, and 1027 A. L. F.	$12·7 \pm 0·76$	$13·9 \pm 0·69$	..	..
B. D. 4, B. D. 6, Selection II and I-A Cylindrical Boll.	..	..	$13·9 \pm 0·95$	$16·5 \pm 1·12$

These figures give, of course, simply the variation of the average from plant to plant, and indicate the difference in this variability from season to season. It tells nothing as to the difference between bolls from various parts of the same plant, or from bolls from flowers formed in different parts of the same season.

(*b*) VARIABILITY OF SEED-WEIGHT AND LINT-WEIGHT PER SEED IN BOLLS FROM DIFFERENT PARTS OF THE SAME SEASON.

We may first discuss the second of these points. It has been claimed by Balls[1] that in a pure strain the cotton from bolls ripening from flowers opening the same

[1] Lecture before the British Association, Liverpool, 1923.

day will be very much less variable from boll to boll than that from flowers opening on different dates, though the variability of different seeds in each boll among themselves will remain. The reason for this, he contended, is that the sprouting of the seed-hairs is determined on the day of flowering. The present study has given an opportunity to investigate how far the contention of Balls is true for pure strains of *Broach-deshi* cotton.

The plan of work adopted in this study, and in those to be described later, was as follows. In four strains in 1923-24 twenty-five plants of average growth were selected and on these the flowers were ticketed daily as they opened, with the date. These were examined, thereafter, every second day so as to note the opening date of the boll. Each boll was harvested, separately wrapped in tissue paper with a note of its position on the plant and the date of the opening of the flowers from which it was formed. Each opened boll was then carefully examined to remove specks, dead seeds, etc. The boll, as a whole, was rejected if it was found to be attacked by bollworm. During the examination, the seeds were counted, and then the produce from each boll was hand-ginned and the weights of seed and lint recorded in milligrams.

The same procedure was adopted in 1924-25 at Surat, except that in two strains 50 plants instead of 25 were fully studied in this way. In the corresponding tests made at Broach, only eleven to thirteen plants were fully studied in each case, as the plants there are larger and the number of bolls per plant very much greater.

The method adopted for recording the position of a boll on these highly monopodial cotton types may be interesting. The position was noted by two, three or four figures. The first indicated the node on the main stem of the plant of the branch from which the boll is borne. The second figure, where the figures were only two, gave the node of the primary fruiting branch on which the boll was carried, or, where the figures were more than two, the node on the vegetative branch of whatever kind, from which the boll arose. The third figure represented, when the figures were only three, the node of the secondary fruiting branch which carried the boll, or (when the figures were four) the node on the tertiary vegetative branch of whatever kind from which the boll was borne. The fourth figure, which only occurred when the bolls were carried on tertiary fruiting branches, indicated the node of the fruiting branch that carried the boll. The cases of secondary fruiting branches arising from primary fruiting branches and of branches arising from accessory buds were not separately considered, and are rare. This system of record enables an accurate comparison to be made of the seed-weight and lint-weight per seed of every boll in relation to its date of flowering, period of maturation, and position on the plant, and the records so obtained are the basis of the discussion now to be made.

Date of flowering and weight of seed and lint. To return now to the effect of date of flowering, the results may be summarized in the following table, in which the variability of (*a*) the seed-weight and (*b*) the lint-weight per seed from all the bolls examined from the strain is compared with that from flowers opening on the same date. The detailed figures are given in Appendix I.

TABLE IV.

Effect of date of flowering on variability of seed-weight and lint-weight per seed.

Strains	COEFFICIENT OF VARIABILITY			
	SEED-WEIGHT		LINT-WEIGHT PER SEED	
	All bolls of strain	Average of bolls from flowers of each date	All bolls of strain	Average of bolls from flowers of each date
1923-24—				
B.-1	12·8±0·27	11·6±1·15	14·3±0·32	12·7±1·25
I-A Long Boll	12·1±0·31	9·4±1·03	15·7±0·40	11·4±1·23
Selection II	12·3±0·24	12·3±1·16	14·7±0·29	13·5±1·25
1027 A. L. F.	15·9±0·32	13·9±1·38	18·7±0·38	15·1±1·48
1924-25—				
1027 A. L. F.	13·1±0·15	11·8±0·97	15·7±0·17	15·3±1·27
nelection II	12·8±0·15	12·1±0·95	16·1±0·18	15·3±1·23
B. D.	12·4±0·19	10·8±0·97	14·4±0·22	14·0±1·13
B. D. 6	16·8±0·20	13·8±0·96	21·3±0·29	18·9±1·30
I-A Cylindrical Boll	13·8±0·18	10·7±0·80	14·7±0·15	13·3±0·01
Selection II (Broach)	15·1±0·23	13·4±1·10	17·8±0·23	17·1±1·39

These figures show that in almost every case the bolls from flowers which opened on the same day are less variable than the general population of bolls, but the difference is not very great. The results given indicate, in fact, that a similar date of flowering does not in any way mean similar seed-weight, or lint-weight per seed, and that there must be some other factor more effective than that at present under discussion. The results are, in fact, not in accord with the expectation of Balls, though they do show that the date of flowering does have *some* effect in determining the final weight of seed or lint.

It might be, however, that the variability of the seed and lint-weight from the produce of flowers opening on the same date is due simply to differences between the produce of *different plants* even in a pure strain. To see how far this has been the case the produce from flowers of the same date, *on the same plant*, was taken at the height of the season in 1924, and the variability among these compared with that above given for a general plant population of the pure strain. The difficulty

in this case is to get a plant with enough flowers opening on a particular date to give reliable data for such variability tests. But in the following cases, from ten to seventeen flowers opened on the same plant on the same date, and the variability of the produce of these was determined.

The variability of the produce, therefore, from a single plant, from a single flowering date, is shown below.

TABLE V.

Variability from a single plant of produce of a single flowering date.

Date of flowering	Number of cases	Co-efficient of variability	
		Seed-weight	Lint-weight
I-A Cylindrical Boll—			
(1) November 24, 1924	10	10·4±1·57	14·0±2·11
(2) November 25, 1924	14	7·6±0·98	9·5±1·20
(3) November 26, 1924	13	9·8±1·29	10·7±14·1
(4) November 28, 1924	12	15·2±2·09	18·8±2·52
(5) December 3, 1924	12	8·0±1·10	14·0±1·94
B. D. 6—			
(1) November 28, 1924	17	22·3±2·58	28·8±3·33
(2) December 2, 1924	10	10·7±1·61	13·2±1·99
(3) December 3, 1924	10	7·3±1·10	9·9±1·50
Selection II—			
(1) November 24, 1924	13	8·2±1·08	10·1±1·33
B. D. 4—			
(1) November 27, 1924	16	9·7±1·16	11·3±1·34

From these figures the *average* variability of seed from bolls on the same plant is as follows :—

Strain	Seed-weight	Lint-weight per seed
I-A Cylindrical Boll	10·2±1·41	13·3±1·84
B. D. 6	13·4±1·76	17·3±2·24
Selection II	8·2±1·08	10·1±1·33
B. D. 4	9·7±1·16	11·3±1·34

If we compared these averages for bolls from flowers for a single day *on the same plant*, with those for bolls from flowers of a single day *on a number of plants of the same strain* (*vide* Appendix I) we find the variability in the two first cases (I-A Cylindrical Boll and B. D-6) to be substantially identical. In the other two cases the figures are from one plant and one date only and can hence not form a basis of judgment. In other words, the variability is the same on the bolls from flowers of a single day on one plant and on a series of plants of the same strain.

While, therefore, the bolls from flowers of a single day are a little less variable than the general population of all bolls of a pure strain, yet, even when a single plant is taken, the difference in the date of opening of the flowers does not account for more than a small proportion of the variability that is found.

(c) Variability in seed-weight and lint-weight per seed and the time required for the maturation of bolls.

The effect of the time required for the ripening of the bolls may now be considered, as a factor in the variability of the seed-weight and the lint-weight per seed. Balls [1] has stated that the seed-weight goes on increasing all the time the boll is developing, and if this is the case the variation in the length of the maturation period may account, in a pure strain grown at a single centre, for differences in both of the characters under study. Before giving the figures obtained in the present study, it may be useful shortly to summarize information regarding the maturation period of Gujarat *herbaceum* cottons as compared with others for which information exists.

King, in a recent publication,[2] has given the mean length of the boll development period on small-boll Upland long-staple varieties in Mississipi as 51·5 days, and for small-boll early varieties as 48·5 days. Balls notes 48 days as the mean maturation period for standard Egyptian Metafifi at Cairo and that it is 8 days longer than this in the middle Delta. Harland[3] reports 51 days as the mean for Sea Island cotton in the West Indies, while Martin, Ballard and Simpson[4] show that it is considerably longer for Pima cotton grown in Arizona than for any commercial variety hitherto reported. It is stated by them that in Lonestar, for early bolls the maturation period varies from 42 to 55 days, while for late bolls it was from 44 to 57 days. In normal Pima bolls the variation was from 45 to 80 days in 1921 and the period of maturation was found to get longer with bolls of later flowering dates. They found Sea Island cotton to give a mean ripening period of 57·6 days, and Mead cotton 56·1 days.

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1 *The Development and Properties of Raw Cotton*, p. 84.
2 *U. S. A. Dept. Agri. Dept. Bull.* 1018 (1922).
3 *West Indies Bull.* XVI, p. 183 (1917).
4 *Jour. Agri. Res.* XXV, pp. 195-208 (1923).

This period has been carefully watched for several of the pure strains now under study, in 1923-24 and 1924-25, both at Surat and Broach, with the following results.

Strain	1923-24		1924-25	
	MATURATION PERIOD		MATURATION PERIOD	
	Range	Average	Range	Average
Surat—	Days	Days	Days	Days
B. 1	44—70	60·9	..	..
1027 A. L. F.	49—74	64·6	59—112	72·4
I-A Long Boll	51—72	64·2	..	..
Selection III	53—74	64·1	47—102	69·4
Broach—				
Selection III	..	..	47—86	71·0
I-A Cylindrical Boll	..	..	59—90	78·2
B. D. 4	..	..	61—90	76·7
B. D. 6	..	..	59—90	72·0

From these figures it will be seen that the variation in the maturation period with these *Broach-deshi* types is as high as for Pima cotton, but the period is *not* greater for later bolls than for earlier ones. On the contrary, in 1923-24 it was less. In 1924-25 the last bolls took a few days less at Surat, while at Broach the earlier bolls ripened more quickly than the rest of the crop except with the strain I-A Cylindrical Boll with which there was practically no difference. The actual figures are given in Appendix II.

It should be noted that the average period of maturation of *Broach-deshi* types of cotton is higher than for any other known variety.[1] It was particularly high in 1924-25, possibly because, in that year, after completion of flowering in the middle of January, there was an universal and severe cold spell.

Now Balls [2] has stated that the weight of the cotton seed goes on increasing all the time of maturation. If the lint-weight per seed increases in the same manner and to the same extent as the seed-weight, or, in other words, if there is perfect

[1] Bryan (*Bull. No. 149 (1924)—Arizona University*—Boll. studies with upland cotton, p. 8), however, gives a longer average maturation period for the Hartsville variety of American cotton, namely, 63 days.

[2] *The Development and Properties of Raw Cotton*, p. 84.

correlation between them, then the variability of each will not be affected by the length of time between flowering and ripening. If, on the other hand, there is no correlation, or if the correlation is only partial, then the length of time of ripening of the boll will affect the one more than the other, and will account, partially at any rate, for the variability. Now the actual correlation between the average seed-weight from each boll and the ripening period in days of each boll is shown in the following table, derived from the study of 343 to 669 cases in 1923-24 and from 940 to 1,730 cases in 1924-25.

TABLE VI.

Correlation between seed-weight and maturation period.

Strain	Correlation co-efficient	
	1923-24	1924-25
Surat—		
B.-1	+0·19±0·030	....
1027 A. L. F.	+0·24±0·027	+0·03
I-A Long Boll	+0·30±0·032	....
Selection III	+0·18±0·018	+0·14±0·016
Broach—		
Selection III	....	+0·04
I-A Cylindrical Boll	....	+0·12±0·019
B. D. 4	....	+0·02
B. D. 6	....	+0·02

It will be seen that in 1923-24 there was a reliable positive correlation between the seed-weight and period of maturation of the bolls, though a very feeble one. In 1924-25, any effect of this kind has been swamped by other factors, possibly by the cold period during the ripening of the bolls which has been referred to above.

This does not answer the question, however, as to whether the length of maturation affects the size of the seed or the weight of lint per seed. A similar correlation

study with regard to the latter has, however, yielded the results shown in the following table.

TABLE VII.

Correlation between lint-weight per seed and maturation period.

Strain	Correlation co-efficient	
	1923-24	1924-25
Surat—		
B.-1	+0·22±0·031	....
1027 A. L. F.	+0·40±0·024	+0·04±0·016
I-A Long Boll	+0·49±0·028	....
Selection II	+0·33±0·023	+0·12±0·017
Broach—		
Selection II	....	+0·22±0·021
I-A Cylindrical Boll	....	+0·21±0·018
B. D. 4	....	+0·19±0·022
B. D. 6	....	—0·021±0·02

The results are similar to those for seed-weight. In general, the lint-weight seems to be more affected by the length of the maturation period of the boils than the seed-weight, though in 1924-25, at Surat, the relation is partly swamped by other factors.

The general result of this study of the question as to whether the variability of the seed-weight and the weight of lint per seed in a pure strain can be explained by differences in date of flowering or in the maturation period of the bolls, is clear. Both of these conditions have *an* effect, though it may be swamped by other factors. But in any case it is entirely inadequate to account for the variability in these characters found regularly in every season in every pure strain. It is clear that we shall have to look elsewhere for the causes of this variation, and it is now proposed to examine the question of the variability among the bolls on each single plant and its cause.

(*d*) VARIABILITY OF SEED-WEIGHT AND LINT-WEIGHT PER SEED FROM BOLL TO BOLL ON A SINGLE PLANT.

It has been already described how full data for every boll on a series of plants were obtained and recorded both in 1923-24 and in 1924-25. The number of bolls

per plant in 1923-24 numbered from 13 to 40, and in 1924-25 from 20 to 40 at Surat, while at Broach in 1924-25 the number was very much larger, varying from 48 to 164.

The variability among the bolls on single plants differed considerably from plant to plant as is shown in the following records.

I. 1923-24—B-I at Surat.

Co-efficient of variability	Number of cases	
	Seed-weight	Lint-weight
Under 5	1	none
From 5—10	3	3
From 10—15	15	15
From 15—20	1	2
Over 20	1	1
Total	21	21

The maximum variability of seed-weight on a plant was $20{\cdot}9 \pm 2{\cdot}87$ and the least $4{\cdot}6 \pm 0{\cdot}63$: for lint-weight per seed the maximum was $21{\cdot}7 \pm 2{\cdot}98$ and the least was $7{\cdot}2 \pm 0{\cdot}99$.

II. 1923-24—I-A Long Boll at Surat.

Co-efficient of variability	Number of cases	
	Seed-weight	Lint-weight
Under 5	none	none
From 5—10	5	none
From 10—15	15	12
From 15—20	1	5
Over 10	none	4
Total	21	21

The highest variability of seed-weight was 16·2±1·65 and the least was 7·5±1·07: for lint-weight per seed, the highest was 25·9±3·56 and the least was 10·3±1·16.

III. 1923-24 and 1924-25—Selection II at Surat.

Co-efficient of variability	1923-24 Number of cases		1924-25 Number of cases	
	Seed-weight	Lint-weight	Seed-weight	Lint-weight
Under 5	none	none	none	none
From 5—10	6	3	19	7
From 10—15	19	16	24	28
From 15—20	none	5	2	8
Over 20	none	1	2	4
Total .	25	25	47	47

Taking the two years together, the highest variability of the seed-weight on a single plant was 21·5±2·14 and the least was 5·5±0·53: for lint-weight per seed, the highest was 31·7±5·15 and the least 8·12±0·99. In both matters, the higher figure was obtained in 1924-25.

IV. 1923-24 and 1924-25—1027 A. L. F. at Surat.

Co-efficient of variability	1923-24 Numbers of cases		1924-25 Number of cases	
	Seed-weight	Lint-weight	Seed-weight	Lint-weight
Under 5	none	none	none	none
From 5—10	1	2	22	11
From 10—15	15	5	24	34
From 15—20	6	11	2	1
Over 20	1	5	2	14
Total .	23	23	50	50

Again, taking the two years together, the highest variability of the seed-weight on a single plant was 20·22±1·50, and the least was 6·5±0·79; for lint-weight per seed, the highest was 28·3±1·82 and the least 7·3±0·89. In both matters the higher figure was obtained in 1924-25.

V. 1924-25—1-A Cylindrical Boll at Broach.

Co-efficient of variability	Number of cases	
	Seed-weight	Lint-weight
Under 5	none	none
From 5—10	1	none
From 10—15	11	11
From 15—20	none	1
Over 20	1	1
Total	13	13

The variability was determined from a number of bolls per plant which ranged from 51 to 146 with an average of 98 bolls. The highest figure for the variability of the seed-weight was 21·5±1·07 and the lowest 10·0±0·39: for lint-weight per seed the maximum was 25·8±1·28 and the lowest 10·8±0·42.

VI. 1924-25—Selection II at Broach.

Co-efficient of variability	Number of cases	
	Seed-weight	Lint-weight
Under 5	none	none
From 5—10	2	none
From 10-15	7	7
From 15—20	1	3
Over 20	2	2
Total	12	12

The variability was determined from a number of bolls per plant which ranged from 52 to 111, with an average of 80 bolls. The highest figure for the variability

of the seed-weight was $20{\cdot}9 \pm 1{\cdot}11$ and the lowest $9{\cdot}3 \pm 0{\cdot}53$; for lint-weight per seed, the maximum was $27{\cdot}8 \pm 1{\cdot}83$ and the lowest $11{\cdot}4 \pm 0{\cdot}60$.

VII. 1924-25—B. D-4 at Broach.

Co-efficient of variability	Number of cases	
	Seed-weight	Lint-weight
Under 5	none	none
From 5—10	2	1
From 10—15	10	9
From 15—20	1	3
Over 20	none	none
Total .	13	13

The variability was determined from a number of bolls per plant which ranged from 48 to 95, with an average of 72 bolls. The highest figure for the variability of the seed-weight was $14{\cdot}4 \pm 0{\cdot}83$ and the lowest $9{\cdot}3 \pm 0{\cdot}48$; for lint-weight per seed the maximum was $19{\cdot}8 \pm 1{\cdot}28$ and the lowest $9{\cdot}9 \pm 0{\cdot}53$.

VIII. 1924-25—B. D. 6 at Broach.

Co-efficient of variability	Number of cases	
	Seed-weight	Lint-weight
Under 5	none	none
From 5—10	none	none
From 10—15	6	1
From 15—20	5	6
Over 20	none	4
Total .	11	11

The variability was determined from a number of bolls per plant which ranged from 72 to 164, with an average of 113 bolls. The highest figure for the variability of the seed-weight was $20{\cdot}0 \pm 0{\cdot}85$ and the lowest $12{\cdot}6 \pm 0{\cdot}77$: for lint-weight per seed the maximum was $25{\cdot}6 \pm 1{\cdot}09$ and the lowest $14{\cdot}1 \pm 0{\cdot}52$.

The general result of the observation just set out is that the lint-weight per seed is far more variable from one boll to another on the same plant than is the seed-weight.

itself, and this in every strain; while the differences of variability from plant to plant are also greater.

There is one thing which might affect the comparisons which have just been made. The number of seeds per boll is not constant but in the figures just given all bolls have been included. But there are generally though not always, a few bolls which contain a *very* small number of seeds. If these are excluded the variability is, however, only slightly, though perceptibly reduced, particularly as to the amount of lint per seed in certain strains. The actual figures obtained in a study of this point in 1923-24 gave results as follows :—

TABLE VIII.

Variability per plant in 1923-24.

—	Co-efficient of variability	
	Seed-weight	Lint-weight
(1) *B-1* (10 plants)—		
(*a*) including all bolls	11·7±1·30	13·0±1·47
(*b*) excluding bolls with very few seeds	11·6±1·26	13·3±1·55
(2) *I-A Long Boll* (7 plants)—		
(*a*) including all bolls	10·6±1·34	17·9±2·17
(*b*) excluding bolls with very few seeds	10·8±1·44	14·0±1·96
(3) *Selection II* (13 plants)—		
(*a*) including all bolls	11·8±1·06	13·9±1·26
(*b*) excluding bolls with very few seeds	11·4±1·08	13·2±1·14
(4) 1027 A. L. F. (9 plants)—		
(*a*) including all bolls	13·4±1·33	14·9±1·49
(*b*) excluding bolls with very few seeds	12·8±1·31	14·1±1·48

Consequently, it seems clear that the variability is only in a very minor measure due to the number of seeds per boll. This is, however, only due to the fact that these abnormal bolls with very few seeds are very small in number: in such bolls as occur, the seed-weight is invariably high in proportion to the amount of lint on each seed. The actual correlation frequency of Selection II at Surat is given in Appendix III. From this it may be seen that all the bolls with few seeds have higher seed-weight and lower lint-weight.

(*e*) Variability of seed-weight and lint-weight per seed due to the kind of branch on which a boll occurs.

The bolls of cotton are borne on three distinct types of branches. There are, first, the primary fruiting branches or sympodia which rise directly from the main stem of the plant. These form the main source of the crop in most cultivated varieties of cotton and even in some types of *herbaceum* cottons. In the *Broach-deshi* types the crop, carried on these primary fruiting branches, does not form such a large proportion of the total as in most other cases.

Secondly, there are the fruiting branches borne on primary monopodia or limbs. These carry a very considerable portion of the total bolls in most of the types of *Broach-deshi* cotton.

Thirdly, there are the fruiting branches which rise from axillary monopodia (limbs) generally in the later part of the growth of the plant.

A very few bolls are not included in these three types, but they are such a small proportion of the total that they may be neglected.

The problem is to see whether there is, within a pure strain, any great or any constant difference between bolls borne on these different types of branches, and the following table gives the average weight in milligrams of the seed and of the lint per seed for each type of branch.

Table IX.

Average weight of seeds and of lint per seed on different kinds of branches.

Strain	Average lint weight per seed			Average seed weight		
	Primary fruiting branches	Branches on primary monopodia	Branches on axillary monopodia	Primary fruiting branches	Branches on primary monopodia	Branches on axillary monopodia
	mg.	mg.	mg.	mg.	mg.	mg.
A.—Surat, 1923-24.						
Selection II	46·9	46·4	47·6	65·0	65·6	64·6
I-A Long Boll	44·0	43·4	44·5	65·5	64·3	64·1
1027 A. L. F.	42·9	41·7	43·2	75·1	75·1	76·2
B-1	33·7	32·8	33·7	58·9	57·5	57·8
B.—Surat, 1924-25.						
Selection II	35·1	34·8	35·6	64·8	63·6	63·9
1027 A. L. F.	41·4	42·4	42·5	73·9	76·7	75·6
C.—Broach, 1924-25.						
Selection II	31·9	32·7	32·0	60·6	62·2	61·7
B. D 6	30·8	28·8	29·7	59·1	57·3	58·0
B. D 4	40·8	40·1	42·0	81·3	77·4	79·5
I-A Cylindrical Boll . . .	42·1	40·7	41·2	69·7	67·2	66·7

As regards seed-weight it is evident that there is no relationship between the kind of branch on which the bolls occur and the average weight. The seeds which grow from branches on the primary or axillary monopodia are equally likely to be heavier or lighter than those which are found on the primary fruiting branches. The question is not quite so clear as regards the lint-weight per seed. In all cases but two, the seeds from bolls arising indirectly from primary monopodia gave less lint than those from primary fruiting branches or from those arising indirectly from axillary monopodia. The difference, however, is very small amounting to only 2 per cent. of the mean weight of lint per seed.

The above table deals with the actual mean value of the seed-weight of lint per seed, but the position will be clearer if the co-efficient of variability in the produce of each type of branch is also considered. This is shown in the following Table.

TABLE X.

Variability of seed weight and weight of lint per seed on different types of branches Co-efficient of variation.

Strain	Lint-weight per seed			Seed-weight		
	Primary fruiting branches	Branches on primary monopodia	Branches on axillary monopodia	Primary fruiting branches	Branches on primary monopodia	Branches on axillary monopodia
A.—Surat, 1924-25.						
Selection II	16·4±0·41	16·8±0·36	15·8±0·29	13·5±0·33	13·5±0·28	11·9±0·21
1027 A. L. F.	21·2±0·66	14·4±0·26	14·8±0·24	17·2±0·53	12·2±0·25	12·2±0·20
B.—Broach, 1924-25.						
Selection II	19·2±0·53	15·8±0·71	16·9±0·36	16·2±0·44	13·3±0·59	14·8±0·32
B. D 6	20·3±0·72	21·4±0·72	21·4±0·37	17·3±0·61	17·6±0·59	16·4±0·28
B. D 4	15·4±0·45	16·5±0·65	13·5±0·29	13·3±0·39	14·4±0·59	11·1±0·23
1-A Cylindrical Boll	15·2±0·59	14·4±0·34	14·7±0·27	14·8±0·57	13·5±0·32	13·2±0·24
AVERAGE	17·9±0·56	16·5±0·51	16·2±0·30	15·3±0·48	14·8±0·45	13·3±0·24

In both characters, the variability of the characters under study is higher in all types except two (B. D 6 and B. D 4) on the primary fruiting branches. On the whole, it may be said with certainty that in pure strains of *Broach-deshi* cotton, the variability due to the type of branch is small, and only accounts for a small proportion of the total amount of variability found.

(*f*) Effect of length of internode on seed-weight and lint-weight per seed.

In a previous publication[1] one of the authors has brought forward data which tend to show a very distinct relationship, in pure strains of *Broach-deshi* cotton, between the length of internodes on the monopodial branches and the occurrence and length of the fruiting branches which arise from them. Wherever there was a short internode on a vegetative branch, the fruiting branches arising from the succeeding node often failed to be produced. But this observation may now be extended. Where a fruiting branch *does* arise after such a short internode, the seed-cotton, which it produces, tends to give a lower seed-weight and a lower weight of lint per seed than the rest of the plant. This point has only, however, been carefully studied for two strains, which in 1921-22 gave figures as follows :—

Strain	Seed-weight		Lint-weight per seed	
	After short internodes	After long internodes	After short internodes	After long internodes
	mg.	mg.	mg.	mg.
1-A Long Boll	59·4	63·9	36·0	38·3
1-A Cylindrical Boll . . .	58·5	62·2	30·6	31·5

This effect of internode length on the character of the seed-cotton on the succeeding branch has also been noted by Saitzeff[2] who also marked with *herbaceum* cottons. He has observed that the length of the internodes always decreases toward the end of the branch, while at the same time, within the limits of the cone, it increases from the bottom to the top of the plant. These differences affect the number of seeds developed in each boll, and also their average weight.

(*g*) Effect of number of seeds in the boll on seed-weight and lint-weight per seed.

It has already been shown (page 178) that when the number of seeds per boll is very low, the seed-weight is much increased, while the weight of lint per seed is decreased. Such cases are, however, few. Saitzeff (*loc. cit.*) has also shown that the number of seeds per boll is lower at the end of branches. In the present enquiry, the average number of seeds per boll from flowers opening on different dates has

[1] *Mem. Dept. Agri. India, Bot. Ser.*, XII, No. 5, p. 195.

[2] Saitzeff. Flowering, Fruit Formation and Dehiscerace of the Bolls of the Cotton Plant, No. 1 (1924).

been determined for two strains. These are Cylindrical Boll and Selection II. The latter is particularly suitable for the purpose as it is the most variable in the number of seeds among all the strains examined.

The general results as to variation in the number of seeds per boll from flowers opening on a certain date is given in the following three tables. The original figures representing the average number for all flowers of a certain date are given in Appendix IV. The present figures show the averages of these figures and the range for seven days, more or less, in each case.

TABLE XI.

Variation in number of seeds per boll.

Flowering dates	Number of seed per boll	
A. Selection II at Broach in 1924-25.		
1924.	Average	Range
Up to November 20	20·6	18·9 to 22·8
November 21 to 27	20·6	18·0 to 22·7
November 28 to December 4	17·8	16·1 to 20·6
December 5 and after	20·4	19·8 to 21·1
General average	19·9	....
B. I-A. Cylindrical Boll at Broach in 1924-25.		
Up to November 20	19·3	18·3 to 20·2
November 21 to 27	20·2	19·1 to 21·1
November 28 to December 4	19·4	18·8 to 20·1
December 5th and after	19·7	19·1 to 20·9
General average	19·6	....
C. Selection II at Surat in 1924-25.		
November 22 to 27	20·4	18·7 to 21·9
November 28 to December 4	20·1	19·2 to 20·6
December 5 to 11	19·3	18·8 to 20·3
December 12 to 18	19·9	19·1 to 20·3
December 19 and after	18·5	17·3 to 19·5
General average	19·5	....

These figures seem to show no regular change in the number of seeds per boll for different parts of the season, which occurs in all strains. In I-A Cylindrical Boll, there seems no effect at all. In Selection II, which is notoriously variable, there is a decided falling off in the number of seeds per boll at the end of the season at Surat, and a little before the end of the season at Broach.

The question immediately arises as to how far the *variability* of the seed-weight and of the lint-weight per seed is greater or less at the different periods of the season. The following table gives evidence on this point.

TABLE XII.

Variability of seed-weight and lint-weight per seed at different parts of the season.

Flowering dates	Coefficient of variation	
	Seed-weight	Lint-weight per seed
Selection II (Broach).		
Up to November 20th	13·4±1·30	16·7±1·64
21st to 27th November	13·0±0·89	17·1±1·15
28th to 30th and after	14·7±1·10	14·3±1·39
I-A Cylindrical Boll (Broach).		
Up to November 20th	9·7±0·90	13·2±1·25
21st to 27th November	11·0±0·75	13·5±0·91
28-11 to 4th December	10·2±0·69	12·5±0·85
5-12 and after	11·1±0·57	13·6±0·95
Selection II (Surat).		
22nd to 27th November	15·0±1·50	18·5±1·82
28-11 to 4th December	13·0±0·94	15·1±1·18
5-12 to 11th December	11·5±0·77	14·7±0·98
12th to 18th December	10·9±0·79	13·7±1·00
19th December and after	10·6±0·85	14·9±1·21

Beyond this, some indirect evidence may be presented. In the first place, the relationship between the seed-weight and the weight of lint per seed is very close, and hence the ginning percentage is less variable than either factor. In spite of this, however, there is a slight—and with one type ("Selection II") a sub-

stantial—positive correlation between the ginning percentage and the number of seeds per boll. The coefficients of correlation are as follows in crops of 1924-25.

Strain	Coefficient of correlation between number of seeds per boll and ginning percentage
1027 A. L. F.	+0·180±0·015
Selection II at Surat	+0·509±0·012
Selection II at Broach	+0·50±0·016
I-A Cylindrical Boll	+0·39±0·016
B. D 4	+0·13±0·021
B. D 6	+0·245±0·018

This would suggest that except in Selection II any connection between the variability of the two factors (seed-weight and lint-weight per seed) involved in ginning percentage and the number of seeds per boll is only slight.

This point becomes still more clear by comparing the coefficient of correlation between the seed-weight and the weight of lint per seed, and that between the weight of seed-cotton (*kapas*) per boll and the ginning percentage of lint. Now the weight of seed-cotton per boll is a combination of (1) the number of seeds, (2) the weight of each seed, and (3) the weight of lint on each seed. On the other hand, the ginning percentage is a combination of the weight of lint per seed and the weight of seed and lint together. Therefore, if the difference in correlation be negligible in the two series of figures noted above, in any strain, we may conclude that in that strain the number of seeds per boll is the disturbing factor. This is only seen in the strain Selection II as the following figures of 1924-25 show.

Strain	Coefficient of correlation between (*a*) weight of seed-cotton per boll, and (*b*) ginning percentage	Coefficient of correlation between (*a*) seed-weight, and (*b*) weight of lint per seed
1027 A. L. F.	+0·308±0·014	+0·623±0·010
Selection II (Surat)	+0·504±0·012	+0·544±0·012
Selection II (Broach)	+0·454±0·017	+0·645±0·012
I-A Cylindrical Boll	+0·387±0·016	+0·666±0·010
B. D-4	+0·130±0·021	+0·666±0·012
B. D-6	+0·492±0·014	+0·831±0·006

There is, therefore, no clear indication, except in strain Selection II, of any very marked connection between the variability of seed-weight and lint-weight per seed, and any *ordinary* variation in the number of seeds per boll. This is not the case, in extreme cases (see page 178) where such a connection has already been shown.

(*h*) Effect of number of cells in the boll on seed-weight and lint-weight per seed.

In a previous Memoir * it has been noted that seeds from four-celled bolls are usually lighter than those from three-celled bolls. How far does this account for the variability of the seed-weight and lint-weight per seed already noted? The number of four-celled bolls is small, and varies much from year to year. The actual difference in the character under study in a number of cases is as follows :—

Strain	Average seed-weight for		Average weight of lint per seed from	
	4-celled bolls	3-celled bolls	4-celled bolls	3-celled bolls
	mg.	mg.	mg.	mg.
B-I in 1921-22	52·9	54·0	29·7	28·9
B-I in 1923-24	59·9	57·8	35·6	33·2
I-A Long Boll in 1921-22	68·0	69·2	48·0	47·0
I-A Long Boll in 1923-24	64·0	65·4	46·2	42·0
Selection II in 1924-25	62·0	64·1	34·8	35·2

Taking all these strains together, it will be seen that on the average the seeds from 4-celled bolls are 1·1 per cent. lighter than from 3-celled bolls. The lint-weight per seed is, however, on the other hand, 4·3 per cent. higher from 4-celled bolls than from 3-celled bolls. In neither case, however, is the relationship consistent in all cases, and it would be very doubtful, especially in the case of the lint-weight per seed, to seek to connect, to a material extent, the variability with the occurrence of 4-celled bolls.

Before proceeding further, it may be wise to summarize the conclusions that have been reached regarding the causes of the variability of seed-weight and lint-weight per seed in pure strains of *Broach-deshi* cotton. These are as follows :—

(1) The seed-weight and lint-weight per seed from flowers opening on a single day are a little less variable than from the whole of the flowers of a strain. This does not account, however, for more than ten per cent. of the total variability for lint weight and for more than twelve per cent. of the total variability for seed-weight.

* *Mem. Dept. Agri. India, Bot. Ser.*, XII, No. 5, p. 214.

(2) The time required for the maturation of the boll would seem to be distinctly but feebly correlated with the seed-weight, though the relationship may easily be swamped by seasonal factors. As regards the lint-weight per seed, the time required for maturation of bolls also affects the weight, and, in fact, to a greater extent than with seed weight. This may be also largely swamped by seasonal factors, as occurred at Surat in 1924-25.

(3) The kind of branch on which the bolls are borne has no relationship with the seed-weight, while with the lint-weight per seed the position is doubtful. There is evidence, however, that the bolls arising indirectly from primary monopodia give less lint per seed than other bolls from the same plants. The variability within the produce from primary fruiting branches is higher than that from other branches.

(4) There seems a definite relationship between the length of internodes on the branches, and the seed-weight and lint-weight per seed on the bolls borne at the succeeding nodes. The seeds from bolls borne after long internodes are heavier and the lint-weight per seed is also greater.

(5) The number of seeds in the boll (except in extreme cases) has not given a clearly marked effect on the seed-weight and weight of lint per seed,—except in certain strains (*e.g.*, Selection II).

(6) Seeds from 4-celled bolls are usually somewhat lighter than those from 3-celled bolls. The lint weight per seed is, however, slightly greater in the case of 4-celled bolls. The connection is not, however, very certain in the latter case.

(*i*) *Effect of position of bolls on the plant on seed-weight and weight of lint per seed.*

It is well known, with a large number of crop plants, that the position relative to what we may call the general scaffolding of the plant has a certain influence on the character of the fruit. To take a case which differs widely from that which we are now discussing, it is found that in wheat* the grains situated about one-third of the distance from the tip of the spike are heavier than the others. Thus it is necessary to examine whether the position of the bolls on the plant affects the characters now under discussion.

On page 167 of the present Memoir, a method has been described by which the position of any boll on a cotton plant can be defined by means of not more than four figures. Thus a boll whose position is defined by the figures 10, 7, 6, 3 is one which is borne at the third node of a tertiary fruiting branch, which rises at the sixth

* Robbins. The Botany of Crop Plant.

node on a secondary monopodium. The last, itself, occurs at the seventh node of a primary monopodium rising from the tenth node on the main stem.

This position enables bolls which are similarly situated, except in one particular, to be compared, and the figures which follow are based on this method.

The comparisons can thus be easily made, but in order for them to be legitimate, it would appear that any flowers which arise abnormally should be excluded from the comparison. There is only one type of such abnormal flowers, amounting to from two to five per cent. of the total cases, which has attracted the authors' attention and which have consequently been excluded. These are the "delayed flowers" which open later than flowers at a younger node on the same branch. These have been systematically omitted in the comparisons which follow:

A. *Effect of position with regard to the main stem.*

TABLE XIII.

Percentage of cases where the seed weight and the weight of lint per seed decreases at the younger nodes.

Strain and place	1923-24		1924-25	
	Seed-weight	Weight of lint per seed	Seed-weight	Weight of lint per seed
	Per cent	Per cent	Per cent	Per cent
B-I (Surat)	74·2	81·0	..	..
1-A Long Boll (Surat)	82·4	79·4	..	..
Selection II (Surat)	67·1	57·5	63·6	63·2
1027 A. L. F. (Surat)	82·5	60·0	69·2	59·1
Selection II (Broach)	..	..	67·5	64·0
1-A Cylindrical Boll (Broach) . . .	..	..	75·3	53·6
B. D-6 (Broach)	..	..	79·5	76·9
B. D-4 (Broach)	..	..	70·0	63·9

(2) The time required for the maturation of the boll would seem to be distinctly but feebly correlated with the seed-weight, though the relationship may easily be swamped by seasonal factors. As regards the lint-weight per seed, the time required for maturation of bolls also affects the weight, and, in fact, to a greater extent than with seed weight. This may be also largely swamped by seasonal factors, as occurred at Surat in 1924-25.

(3) The kind of branch on which the bolls are borne has no relationship with the seed-weight, while with the lint-weight per seed the position is doubtful. There is evidence, however, that the bolls arising indirectly from primary monopodia give less lint per seed than other bolls from the same plants. The variability within the produce from primary fruiting branches is higher than that from other branches.

(4) There seems a definite relationship between the length of internodes on the branches, and the seed-weight and lint-weight per seed on the bolls borne at the succeeding nodes. The seeds from bolls borne after long internodes are heavier and the lint-weight per seed is also greater.

(5) The number of seeds in the boll (except in extreme cases) has not given a clearly marked effect on the seed-weight and weight of lint per seed, —except in certain strains (*e.g.*, Selection II).

(6) Seeds from 4-celled bolls are usually somewhat lighter than those from 3-celled bolls. The lint weight per seed is, however, slightly greater in the case of 4-celled bolls. The connection is not, however, very certain in the latter case.

(*i*) *Effect of position of bolls on the plant on seed-weight and weight of lint per seed.*

It is well known, with a large number of crop plants, that the position relative to what we may call the general scaffolding of the plant has a certain influence on the character of the fruit. To take a case which differs widely from that which we are now discussing, it is found that in wheat* the grains situated about one-third of the distance from the tip of the spike are heavier than the others. Thus it is necessary to examine whether the position of the bolls on the plant affects the characters now under discussion.

On page 167 of the present Memoir, a method has been described by which the position of any boll on a cotton plant can be defined by means of not more than four figures. Thus a boll whose position is defined by the figures 10, 7, 6, 3 is one which is borne at the third node of a tertiary fruiting branch, which rises at the sixth

* Robbins. The Botany of Crop Plant.

node on a secondary monopodium. The last, itself, occurs at the seventh node of a primary monopodium rising from the tenth node on the main stem.

This position enables bolls which are similarly situated, except in one particular, to be compared, and the figures which follow are based on this method.

The comparisons can thus be easily made, but in order for them to be legitimate, it would appear that any flowers which arise abnormally should be excluded from the comparison. There is only one type of such abnormal flowers, amounting to from two to five per cent. of the total cases, which has attracted the authors' attention and which have consequently been excluded. These are the "delayed flowers" which open later than flowers at a younger node on the same branch. These have been systematically omitted in the comparisons which follow :

A. *Effect of position with regard to the main stem.*

TABLE XIII.

Percentage of cases where the seed weight and the weight of lint per seed decreases at the younger nodes.

Strain and place	1923-24		1924-25	
	Seed-weight	Weight of lint per seed	Seed-weight	Weight of lint per seed
	Per cent	Per cent	Per cent	Per cent
B-I (Surat)	74·2	81·0	..	..
I-A Long Boll (Surat)	82·4	79·4	..	..
Selection II (Surat)	67·1	57·5	63·6	63·2
1027 A. L. F. (Surat)	82·5	60·0	69·2	59·1
Selection II (Broach)	..	..	67·5	64·0
I-A Cylindrical Boll (Broach) . . .	..	..	75·3	53·6
B. D-6 (Broach)	..	..	79·5	76·9
B. D-4 (Broach)	..	..	70·0	63·9

B. *Effect of position with regard to primary monopodia and axillary vegetative branches.*

TABLE XIV.

Percentage of cases where the seed weight and the weight of lint per seed decreases at the younger nodes.

Strain and place	1923-24		1924-25	
	Seed-weight	Weight of lint per seed	Seed-weight	Weight of lint per seed
	Per cent.	Per cent.	Per cent.	Per cent.
B-I (Surat)	70·7	67·2	..	..
I-A Long Boll (Surat)	68·5	66·7	..	..
Selection II (Surat)	69·1	67·4	68·2	68·4
1027 A. L. F. (Surat)	78·4	60·7	68·2	66·4
Selection II (Broach)	..	..	71·4	67·1
I-A Cylindrical Boll (Broach)	..	..	74·1	62·2
B. D-6 (Broach)	..	..	79·9	76·5
B. D-4 (Broach)	..	..	75·1	64·2

C. *Effect of position with regard to primary or secondary sympodia.*

TABLE XV.

Percentage of cases where the seed-weight and the weight of lint per seed decreases at the younger nodes.

Strain and place	1923-24		1924-25	
	Seed-weight	Weight of lint per seed	Seed-weight	Weight of lint per seed
	Per cent.	Per cent.	Per cent.	Per cent.
B-I (Surat)	91·0	87·9	..	..
I-A Long Boll (Surat)	76·9	92·3	..	..
Selection II (Surat)	85·2	70·0	82·5	77·5
1027 A. L. F. (Surat)	85·2	70·4	81·2	73·3
Selection II (Broach)	79·6	75·3	86·1	80·6
I-A Cylindrical Boll (Broach)	92·4	68·4	89·3	76·1
B. D-6 (Broach)	77·3	71·1	87·1	81·6
B. D-4 (Broach)	..	..	89·5	74·4

The results of these comparison are of interest. As one progresses along from the older parts of one type of branch to the younger, in the majority of cases both the seed-weight and the weight of lint per seed decrease. This is especially marked in the case of the sympodial branches which directly bear bolls themselves, and with these branches generally this decrease is shown in over 80 per cent. and in a few cases in over 90 per cent. of cases.

The progressive decrease at the younger nodes on the vegetative branches and on the main stem is not so marked though the tendency seems to exist in both classes of branches.

There is a practical consequence from a breeding point of view, which arises from this result. For the purpose of having large seeds and a large weight of lint per seed, a type of plant should be preferred which has numerous short branches, and especially numerous short sympodia, rather than one which has long branches and especially one which relies for its yield on a limited number of long fruiting branches.

So far we have considered the *proportion of cases* in which the characters under study decrease as progress is made from the older to the younger parts of the same class of branches. *Now*, we may consider the actual amount of variability, or in other words, the extent of the decrease with each type of branch. And, here, it is necessary to limit all results to those cases where bolls are actually borne on *successive* nodes on a branch. If there are nodes on which no bolls occur between two on which bolls actually are formed, other influences than that of position may affect the result. Hence in the following tables only those cases where the bolls are on *successive* nodes are taken into account.

A. *Effect of position with regard to the main stem.*

TABLE XVI.

Average decrease in seed-weight and weight in lint per seed on consecutive nodes.

Strain and place	1923-24		1924-25	
	Seed-weight	Weight of lint per seed	Seed-weight	Weight of lint per seed
	mg.	mg.	mg.	mg.
B-I (Surat)	6·1	5·6	..	..
I-A Long Boll (Surat)	2·4	3·8	..	..
Selection II (Surat)	4·6	2·3	0·7	0·6
1027 A. L. F. (Surat)	8·3	2·3	1·7	1·2
Selection II (Broach)	..	..	3·8	2·6
I-A Cylindrical Boll (Broach)	..	..	1·9	0·07 (Increase)
B. D-6 (Broach)	..	..	5·7	4·2
B. D-4 (Broach)	..	..	3·7	1·7

B. *Effect of position with regard to the primary monopodia and axillary vegetative branches.*

TABLE XVII.

Average decrease in seed-weight and weight of lint per seed on consecutive nodes.

Strain and place	1923-24		1924-25	
	Seed-weight	Weight of lint per seed	Seed-weight	Weight of lint per seed
	mg.	mg.	mg.	mg.
B-1 (Surat)	5·7	4·5	..	..
I-A Long Boll (Surat)	2·3	3·0	..	..
Selection II (Surat)	1·3	2·2	3·4	1·8
1027 A. L. F. (Surat)	4·9	4·0	4·3	2·4
Selection II (Broach)	..	..	4·2	1·8
I-A Cylindrical Boll (Broach)	..	..	2·9	1·6
B. D-6 (Broach)	..	..	5·5	3·1
B. D-4 (Broach)	..	..	4·8	1·8

C. *Effect of position with regard to primary and secondary sympodia.*

TABLE XVIII.

Average decrease in seed-weight and weight of lint per seed on consecutive nodes.

Strain and place	1923-24		1924-25	
	Seed-weight	Weight of lint per seed	Seed-weight	Weight of lint per seed
	mg.	mg.	mg.	mg.
B-I (Surat)	11·2	5·0	..	..
I-A Long Boll (Surat)	8·6	9·9	..	..
Selection II (Surat)	7·4	6·4	7·5	4·1
1027 A. L. F. (Surat)	15·8	8·0	7·7	3·2
Selection II (Broach)	2·8	2·0	7·3	4·0
I-A Cylindrical Boll (Broach)	7·2	3·4	8·7	3·2
B. D-6 (Broach)	3·0	1·7	8·6	4·7
B. D-4 (Broach)	..	..	9·4	4·4

It will be seen from these figures that the mean decrease in seed-weight, for a difference of one node in position on the fruiting branches, amounts to from 10 0 per cent. to 20·9 per cent. of the total seed-weight, and from 7·5 per cent. to 22·2 per cent. of the total weight of lint per seed. The mean decrease per node of position in the case of the monopodial branches is about half of that on the sympodia, and the mean decrease per node of position in the case of the main stem is again far lower in the case of seed-weight, being less than one-third of that on the sympodia, while in the case of the weight of lint per seed it is about half that found on the sympodial branches.

Effect of the position on the ginning percentage.

An important consideration in connection with these figures is as to whether the change in the seed-weight and the weight of lint per seed on account of position on the plant is similar. If it is similar, then the ginning percentage will not be affected; if it is different, the produce of bolls borne on the older or younger parts of the plant will have a different, ginning percentage. In actual practice, this difference will mean that the ginning percentage of the early part of a season will be different from that in the later part of the crop.

The evidence collected on this point is only sufficient in 1924-25 to give any sound conclusion, but here we are able to compare the mean percentage of decrease per node in the seed-weight and in the weight of lint per seed, in each type of branch. The results are somewhat variable in the different strains, but they may be given for each of them.

TABLE XIX.

Percentage decrease in seed-weight and weight of lint per seed for each node on various types of branches.

1924-25.

Strain and place	Main strain		Vegetative branches		Fruiting branches	
	Seed-weight	Weight of lint per seed	Seed-weight	Weight of lint per seed	Seed-weight	Weight of lint per seed
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Selection II (Surat)	1·1	1·7	5·4	5·0	11·6	11·4
1027 A. L. F. (Surat)	2·3	2·8	5·6	5·7	10·0	7·6
Selection II (Broach)	6·1	7·8	6·9	5·6	11·8	12·1
I-A Cylindrical Boll (Broach)	2·8	0·2 (Increase)	4·3	3·8	12·5	7·5
B. D-6 (Broach)	9·5	12·9	9·5	10·4	14·2	15·3
B. D-4 (Broach)	4·4	4·0	6·1	4·3	11·5	10·5

The results are obviously inconclusive. On the sympodia (fruiting branches) where the loss in weight of both the seed and the lint per seed is most considerable, this loss is greater in the case of the seed in four strains, and less in two strains out of the six studied. With regard to the position from the point of view of the main stem, the loss of weight is less in the case of the seed in four cases, and greater in two cases out of six studied. Considering the vegetative branches, in four cases out of six the seed-weight loses more than the lint, while in two cases the opposite is true. No definite conclusion can, therefore, be reached, but if any thing there is perhaps a tendency for the lint weight per seed to diminish faster than the seed-weight in the later developed parts of the plant, or, in other words, for the ginning percentage to be slightly less in the later part of the season. The strains differ in the extent to which this is true, and I-A Cylindrical Boll and B. D-4 as grown at Broach seem to show a very marked tendency in the opposite direction, while B. D-6 shows less decrease in seed-weight on all kinds of branches.

So far, in this Memoir, the study of variability has been limited to the seed-weight and the weight of lint per seed, and it has not been possible to examine more than any generally, the variability of other characters. Figures have, however, been collected indicating, by means of the co-efficient of variation, how far a number of other characters have varied in two years (1923-24 and 1924-25) in the general population of *bolls* grown at one place (Surat or Broach). The characters studied, in addition to the seed-weight and the weight of lint per seed were (1) the number of seeds per boll, (2) the weight of seed-cotton per boll, (3) the maturation period of the bolls, and (4) the ginning percentage of the seed-cotton from boll to boll. The results are given in the following Table.—

TABLE XX.

Co-efficient of variation of certain characters in pure strains of Broach-deshi cotton.

Strain place	Seed-weight	Weight of lint per seed	Number of seeds per boll	Seed-cotton per boll	Maturation period	Ginning percentage
1923-24						
B. 1 (Surat)	12·8±0·27	14·3±0·32	15·2±0·33	20·8±0·46	5·5±0·12	6·8±0·15
1027 A. L. F. (Surat)	15·9±0·37	18·7±0·38	11·4±0·22	19·4±0·38	4·3±0·89	9·8±0·19
I-A Long Boll (Surat)	12·1±0·31	15·7±0·40	16·6±0·42	22·8±0·80	4·6±0·12	8·1±0·20
Selection II (Surat)	12·3±0·24	14·7±0·29	16·8±0·47	20·0±0·36	4·1±0·77	7·2±0·13
1924-25						
1027 A. L. F. (Surat)	13·1±0·15	15·7±0·17	12·2±0·13	16·9±0·19	5·2±0·07	8·3±0·10
Selection II (Surat)	12·8±0·15	16·1±0·18	16·6±0·19	21·2±0·25	5·9±0·07	9·2±0·10
Selection II (Broach)	15·1±0·23	17·8±0·27	20·1±0·30	26·0±0·39	6·8±0·10	8·9±0·13
I-A Cylindrical Boll (Broach)	13·8±0·18	14·7±0·15	15·4±0·20	19·3±0·25	5·4±0·07	6·8±0·09
B. D-4 (Broach)	12·4±0·19	14·4±0·22	11·5±0·18	17·2±0·26	5·5±0·09	7·5±0·11
B. D-6 (Broach)	16·8±0·20	21·3±0·29	12·3±0·12	21·5±0·29	5·7±0·09	7·8±0·10

Most of these characters are very variable, even in the same season at one place, with a strain grown in pure line. The maturation period varies the least of the characters studied. The weight of seed-cotton per boll varies the most. Where plants are grown widely spaced, so that the yield per plant is increased, the variability of the produce increases. This can be seen in the higher variability of Selection II grown at Broach where the plants are spaced at double the distance and the yield per plant was much higher.

III. General Conclusions.

The conclusions reached up to a certain stage of the inquiry described in the present Memoir have been already detailed on page 185 and the results reached in the later part of the investigation only have to be added at this stage. These latter concern mainly the effect of the position of a boll in connection with the scaffolding of the cotton plant on the seed-weight or the weight of lint per seed of the cotton produced. This question of position relative to the general structure of the plant seems a very important factor in determining the variability of the characters studied. Generally, there seems a marked tendency for both the characters to decrease in the later developed parts of the plant, and in the younger parts of branches. This is specially marked in the case of sympodial branches. The extent of decrease is also very high on this kind of branches. This leads one to conclude that a type of plant should be preferred which has numerous short sympodia rather than the one which has a limited number of long fruiting branches.

There is another important point besides the variation and the extent of variation above stated, *viz.*, whether the change in the seed-weight and the weight of lint is similar, or, in other words, whether the ginning percentage remains constant. No definite conclusion may be reached but there seems to be tendency for the lint-weight per seed to diminish faster than the seed-weight, *i.e.*, for the ginning percentage to be less on the younger parts of shoots. The strains differ as to this feature and certain among them, notably I-A Cylindrical Boll and B. D-4 show the opposite tendency, particularly the former.

Out of the several characters studied for variation from boll to boll, it is concluded that the weight of seed-cotton per boll varies the most while the maturation period varies the least.

APPENDIX I.

Variability of seed-weight and weight of lint per seed from flowers opening at different parts of the season, 1923-24.

B-I.

Date of flowering	Co-efficient of variability	
	Seed-weight	Lint-weight per seed
1923		
December 1-7	9·1±0·88	9·0±0·87
December 8-14	10·0±0·60	8·6±0·51
December 15	11·3±1·55	9·3±1·28
December 16-18	9·6±1·02	10·1±1·07
December 19-20	11·2±1·01	11·3±1·02
December 21-22	11·4±1·02	12·6±1·13
December 23	13·3±1·38	15·8±1·64
December 24	13·0±1·55	13·9±1·65
December 25	9·4±1·05	12·8±1·44
December 26	14·0±1·37	11·8±1·17
December 27-28	14·1±1·29	14·1±1·29
December 29-30	13·1±1·51	14·9±1·72
December 31	13·4±1·50	15·6±1·75
1924		
January 1-6	11·8±0·80	13·4±0·85
January 7-19	9·5±0·80	16·8±1·41
Average	11·6±1·15	12·7±1·25
All bolls of the strain	12·8±0·27	14·3±0·32

I-A Long Boll.

Date of flowering	Co-efficient of variability	
	Seed-weight	Lint-weight per seed
1923		
December 1-7	6·9±0·95	9·2±1·26
December 8-14	7·7±0·70	8·9±0·81
December 15-16	9·0±1·29	8·2±1·17
December 17-18	8·7±1·10	8·9±1·13
December 19-20	6·6±0·70	10·8±1·11
December 21-22	10·5±1·09	13·3±1·38
December 23-24	9·5±1·01	10·5±1·12
December 25-26	10·0±0·99	12·9±1·28
December 27	13·0±1·29	14·1±1·40
December 28	13·4±1·65	15·5±1·91
December 29	6·4±0·88	10·2±1·40
December 30	8·9±0·92	12·5±1 30
December 31	9·3±1·02	8·9±0·97
1924		
January 1-6	....	....
January 7-19	12·4±0·81	16·0±1·04
	9·4±1·03	11·4±1·23
All bolls of the strain	12·1±0·31	15·7±0·40

Selection II.

Date of flowering	Co-efficient of variability	
	Seed-weight	Lint-weight per seed
1923		
December 1-7	10·4±0·62	13·5±0·81
December 8-14	11·5±0·58	12·5±0·63
December 15	11·3±1·20	9·8±1·04
December 16	12·8±1·76	10·7±1·47
December 17	9·1±0·90	12·9±1·28
December 18	13·7±1·42	14·0±1·45
December 19-20	12·9±1·34	10·8±1·18
December 21	10·8±1·24	11·9±1·37
December 22	11·2±1·04	12·1±1·13
December 23-24	14·8±1·24	13·8±1·16
December 25	13·7±1·30	18·5±1·76
December 26-27	14·4±1·17	13·3±1·08
December 28	14·6±1·64	16·1±1·81
December 29	15·1±1·80	13·6±1·61
December 30	11·2±1·11	15·9±1·29
December 31	12·1±1·23	15·9±1·61
1924		
January 1-6	12·7±0·74	15·3±0·89
January 7-19	9·1±0·74	11·9±0·97
	12·3±1·16	13·5±1·25
All bolls of the strain	12·3±0·24	14·7±0·29

1027 A. L. F.

Date of flowering	Co-efficient of variability	
	Seed-weight	Lint-weight per seed
1923		
December 1-7	9·8±0·91	12·7±1·18
December 8-14	9·6±0·58	12·3±0·73
December 15	9·4±0·89	10·0±1·06
December 16	10·4±1·03	14·3±1·42
December 17-18	10·4±0·92	9·8±0·86
December 19-20	7·6±0·74	10·3±1·00
December 21	13·5±1·39	12·9±1·28
December 22	16·5±1·91	12·5±1·44
December 23	13·6±1·57	12·3±1·42
December 24	17·4±1·95	15·5±1·74
December 25	17·6±1·58	17·0±1·53
December 26	14·0±1·22	18·9±1·64
December 27	16·2±1·82	15·4±1·73
December 28	14·7±1·22	20·4±1·69
December 29	14·7±1·53	19·5±2·03
December 30	19·3±2·77	13·1±1·88
December 31	19·4±2·12	22·4±2·45
1924		
January 1-6	17·0±1·12	19·1±1·26
January 7-19	13·4±1·02	18·8±1·43
	13·9±1·38	15·1±1·48
All bolls of the strain	15·9±0·32	18·7±0·38

Variability of seed-weight and weight of lint per seed from flowers opening at different parts of the season, 1924-25.

1027 A. L. F.

Date of flowering	Co-efficient of variability	
	Seed-weight	Lint-weight per seed
1924-25		
Before November 23	15·91±1·28	17·57±1·41
November 23	10·25±0·79	14·76±1·12
November 24	11·25±0·99	14·34±1·26
November 25	10·24±1·04	13·02±1·32
November 26	13·22±1·03	17·28±1·35
November 27	14·95±1·36	21·83±1·81
November 28	9·16±0·69	13·16±0·99
November 29	15·00±0·93	18·4 ±1·13
November 30	14·73±0·94	14·66±0·94
December 1	9·52±0·65	12·68±0·87
December 2	12·08±0·76	14·53±0·90
December 3	18·55±1·10	16·56±0·98
December 4	11·62±0·50	13·89±0·60
December 5	11·77±0·62	14·90±0·79
December 6	12·24±0·54	13·64±0·65
December 7	11·82±0·73	17·24±1·07
December 8	12·32±0·78	16·87±1·07
December 9	12·05±0·61	13·26±0·73
December 10	10·12±1·10	16·26±1·78
December 11	9·53±0·43	13·09±0·60
December 12	11·67±1·07	10·41±0·95
December 13	10·11±0·85	15·13±1·27
December 14	10·74±0·68	15·71±1·00
December 15	11·44±0·67	14·51±0·85
December 16	13·28±0·87	17·24±0·87
December 17	13·2±1·04	18·80±1·47
December 18	9·94±0·77	11·18±0·86
December 19	12·05±1·10	15·07±1·38
December 20	8·77±1·08	12·01±1·48
December 21	9·00±1·24	16·8±2·31
December 22	15·46±1·73	18·10±2·03
December 23	7·89±0·82	11·4±1·21
December 24	11·42±1·21	13·36±1·42
December 25	16·69±2·4	29·6±4·25
December 26	11·12±1·47	13·1 ±1·73
December 29 and after	7·71±0·92	10·55±1·25
All bolls together	13·08±0·15	15·68±0·17
Average	11·8 ±0·97	15·3 ±1·27

Selection II.

Date of flowering	Co-efficient of variability	
	Seed-weight	Lint-weight per seed
1924-25		
Before November 23	12·87±0·68	16·30±0·86
November 23	16·60±2·50	17·70±2·67
November 24	13·94±1·35	20·5 ±2·00
November 25	18·40±1·83	21·06±2·09
November 26	12·82±1·00	14·92±1·17
November 27	15·67±1·63	20·73±2·15
November 28	14·15±1·09	15·80±1·22
November 29	14·68±0·97	16·29±1·07
November 30	12·85±0·99	14·01±1·08
December 1	12·93±0·90	16·89±1·16
December 2	13·81±1·02	15·98±1·19
December 3	12·01±0·86	13·27±0·86
December 4	10·69±0·73	13·19±0·90
December 5	11·49±0·72	12·25±0·77
December 6	12·31±0·68	14·63±0·81
December 7	12·35±0·95	15·27±1·18
December 8	8·79±0·56	13·76±0·87
December 9	10·13±0·60	14·37±0·86
December 10	12·20±1·14	15·34±1·43
December 11	13·10±0·71	17·08±0·93
December 12	9·71±0·83	13·72±1·17
December 13	8·35±0·66	10·38±0·82
December 14	10·72±0·74	11·37±0·79
December 15	11·01±0·58	15·17±0·80
December 16	13·36±1·14	16·46±1·40
December 17	11·58±0·80	13·08±0·91
December 18	11·90±0·82	15·62±1·08
December 19	11·29±0·80	14·62±1·03
December 20	10·39±0·97	16·83±1·57
December 21	13·07±0·89	15·07±1·02
December 22	7·41±0·73	13·07±1·29
December 23	11·73±0·93	16·36±1·30
December 24	9·60±0·80	16·14±1·35
December 25	10·03±1·15	12·00±1·38
December 26	11·08±0·54	15·4 ±0·75
December 29 and after	....	....
All bolls together	12·83±0·15	16·09±0·18
Average	12·1 ±0·95	15·28±1·23

B. D-4.

Date of flowering	Seed-weight	Weight of lint per seed
1924-25		
November 14 and before	10·59±0·79	12·54±0·93
November 15-19	8·57±0·73	12·39±1·06
November 20	9·74±1·01	14·50±1·51
November 21	14·35±1·57	23·70±2·59
November 22	12·01±1·58	13·19±1·74
November 23	8·65±0·87	11·44±1·16
November 24	13·35±1·00	17·68±1·14
November 25	12·1 ±0·92	14·38±1·10
November 26	8·20±0·51	10·66±0·66
November 27	8·81±0·53	12·49±0·76
November 28	11·24±0·71	13·82±0·87
November 29	11·51±1·03	13·35±1·20
November 30	9·45±0·71	11·82±0·89
December 1	11·73±0·74	14·82±0·83
December 2	10·53±0·82	12·33±0·96
December 3	11·3 ±0·76	11·29±0·78
December 4	9·23±0·67	14·00±1·01
December 5	11·88±0·89	15·17±1·22
December 6	11·99±0·85	15·28±1·08
December 7	11·54±1·17	17·64±1·79
December 8	8·86±0·90	10·81±1·09
December 9	11·83±0·53	14·55±0·65
and after without date	11·21±0·75	13·88±0·93
Bolls together	12·36±0·19	14·38±0·22
AVERAGE	10·81±0·87	13·99±1·13

B. D-6.

Date of flowering	Seed-weight	Weight of lint per seed
1924-25		
November 14 and before	11·27±1·07	15·6 ±1·48
November 15-18	9·32±0·84	14·61±1·31
November 19-21	10·81±0·82	14·8 ±1·13
November 22	10·2 ±0·91	15·6 ±1·40
November 23	14·86±1·58	18·67±1·98
November 24	11·68±0·64	15·35±0·92
November 25	12·61±0·85	17·5 ±1·16
November 26	14·8 ±0·83	21·21±1·18
November 27	16·1 ±0·92	20·6 ±1·17
November 28	15·20±0·80	20·1 ±1·06
November 29	13·08±0·87	15·30±1·02
November 30	10·9 ±0·89	14·6 ±1·19
December 1	14·90±0·79	21·87±1·16
December 2	14·7 ±0·86	19·38±1·19
December 3	16·36±0·95	21·59±1·16
December 4	16·2 ±0·91	22·2 ±1·25
December 5	16·2 ±1·02	20·9 ±1·3
December 6	14·95±0·87	21·57±1·26
December 7	12·54±1·13	18·13±1·63
December 8	13·4 ±0·83	19·16±1·1
December 9	13·1 ±0·57	19·5 ±0·76
and after without date.	22·07±2·29	27·3 ±2·85
Bolls together	16·8 ±0·20	21·3 ±0·29
AVERAGE	13·85±0·96	18·9 ±1·30

I-A Cylindrical Boll.

Date of flowering	Seed-weight	Weight of lint per seed
1924-25		
November 14 and before	8·96±0·50	11·99±0·67
November 15	6·61±0·72	11·19±1·22
November 16	14·36±1·42	18·31±1·82
November 17	9·18±1·06	15·66±1·81
November 18	8·02±0·83	12·75±1·32
November 19	9·61±0·95	11·12±1·10
November 20	11·34±0·83	10·63±0·78
November 21	9·06±0·90	9·45±0·94
November 22	11·8 ±1·04	13·19±1·16
November 23	10·17±0·74	14·43±1·06
November 24	11·69±0·62	15·09±0·81
November 25	9·97±0·56	12·85±0·72
November 26	8·94±0·53	11·97±0·71
November 27	15·18±0·87	17·37±1·00
November 28	12·82±0·77	15·81±0·94
November 29	8·64±0·71	11·97±0·99
November 30	10·46±0·75	12·79±0·92
December 1	10·51±0·64	13·02±0·79
December 2	11·26±0·76	13·51±0·92
December 3	9·30±0·56	11·17±0·68
December 4	8·44±0·64	8·94±0·69
December 5	11·69±0·78	15·52±1·03
December 6	12·56±0·90	16·13±1·08
December 7	9·18±1·03	11·28±1·27
December 8	8·91±0·77	8·75±0·76
December 9	13·33±0·51	16·40±0·63
After without date	18·12±1·31	18·90±1·37
and all the bolls together	13·82±0·18	14·68±0·15
Average	10·74±0·80	13·34±1·01

Selection II (Broach).

Date of flowering	Seed-weight	Weight of lint per seed
1924-25		
November 11 and before	10·9 ± 0·58	14·1 ± 0·74
November 15	11·6 ± 1·66	13·66 ± 1·96
November 16	14·6 ± 1·80	23·5 ± 2·89
November 17	11·7 ± 1·09	13·07 ± 1·22
November 18	17·2 ± 1·45	20·8 ± 1·75
November 19	14·04 ± 1·24	18·1 ± 1·60
November 20	13·82 ± 1·30	13·85 ± 1·32
November 21	13·9 ± 0·98	16·8 ± 1·19
November 22	12·3 ± 0·91	15·44 ± 1·15
November 23	11·8 ± 0·89	15·62 ± 1·18
November 24	12·29 ± 0·75	17·4 ± 1·03
November 25	15·01 ± 0·88	19·7 ± 1·16
November 26	12·82 ± 0·86	18·55 ± 1·25
November 27	12·7 ± 0·95	15·9 ± 1·08
November 28	16·7 ± 1·34	19·9 ± 1·60
November 29	13·3 ± 1·6	17·56 ± 2·1
November 30 and after	14·05 ± 0·37	17·5 ± 0·47
All bolls together	15·07 ± 0·23	17·83 ± 0·23
Average	13·45 ± 1·10	17·14 ± 1·39

APPENDIX II.

Average number of days of maturity of bolls, 1923-24 (Surat).

SELECTION II.

Date of flowering	No. of days
November 28 and before	63·6
November 29	62·4
November 30	61·5
December 1-2	64·0
December 4	64·2
December 5	62·5
December 6	64·2
December 7	62·0
December 8	64·3
December 9	66·0
December 10	64·9
December 11	65·8
December 12	67·0
December 13	65·4
December 14	64·9
December 15	65·2
December 16	65·6
December 17	65·8
December 18	65·8
December 19	65·8
December 20	65·1
December 21	65·6
December 22	65·5
December 23	65·5
December 24	63·9
December 25	64·8
December 26	64·3
December 27	64·2
December 28	64·3
December 29	64·3
December 30	63·8
December 31	64·0
January 1	62·8
January 2	63·3
January 3	63·1
January 4	63·0
January 5	63·2
January 6	61·9
January 7	59·2
January 8-9	61·1
January 10	60·0

D

I-A Long Boll.

Date of flowering	No. of days
December 9 and before	65·0
December 10-11	65·2
December 12-14	67·6
December 15	66·8
December 16	66·2
December 17	66·1
December 18	65·2
December 19	65·7
December 20	65·9
December 21	66·3
December 22	64·7
December 23	65·2
December 24	64·0
December 25	63·7
December 26	65·9
December 27	64·8
December 28	64·6
December 29	63·7
December 30	63·7
December 31	64·7
January 1	64·0
January 2	64·4
January 3	63·6
January 4	62·8
January 5	64·5
January 6	64·0
January 7	61·2
January 8	62·7
January 9	61·4
January 10	60·3

B.-I.

Date of flowering	No. of days
December 5 and before	60·9
December 6	59·0
December 7	60·9
December 8	59·3
December 9	62·1
December 10	60·3
December 11	61·6
December 12	63·7
December 13	62·0
December 14	61·6
December 15	63·7
December 16	65·0

B.-I.—*contd.*

Date of flowering	No. of days
December 17	62·5
December 18	64·2
December 19	62·6
December 20	62·7
December 21	62·9
December 22	62·8
December 23	62·8
December 24	62·1
December 25	62·0
December 26	61·4
December 27	60·6
December 28	61·0
December 29	60·0
December 30	59·3
December 31	60·5
January 1	59·3
January 2	59·5
January 3	59·7
January 4	57·9
January 5	56·6
January 6	56·7

1027 A. L. F.

Date of flowering	No. of days
December 6 and before	64·7
December 7	65·5
December 8	65·2
December 9	65·4
December 10	65·1
December 11	65·8
December 12	67·4
December 13	66·8
December 14	66·9
December 15	65·0
December 16	66·8
December 17	66·3
December 18	66·3
December 19	66·4
December 20	64·7
December 21	65·1
December 22	65·6
December 23	64·9
December 24	64·7
December 25	64·1
December 26	65·1
December 27	64·2
December 28	65·1

1027 A. L. F.—*contd.*

Date of flowering	No. of days
December 29	64·9
December 30	64·4
December 31	62·6
January 1	63·3
January 2	64·4
January 3	61·9
January 4	63·2
January 5	60·5
January 10	60·2

1924-25.

1027 A. L. F.

Date of flowering	No. of days
November 22 and before	74·0
November 23	70·4
November 24	70·5
November 25	71·7
November 26	72·9
November 27	72·2
November 28	74·1
November 29	71·8
November 30	71·9
December 1	71·2
December 2	72·8
December 3	73·1
December 4	72·8
December 5	73·3
December 6	72·7
December 7	73·2
December 8	72·6
December 9	73·0
December 10	73·2
December 11	72·9
December 12	72·0
December 13	70·3
December 14	71·3
December 15	71·8
December 16	72·6
December 17	72·8
December 18	72·3
December 19	72·0
December 20	70·9
December 21	71·4
December 22	72·2
December 23	72·2

1924-25—*contd.*

1027 A. L. F.—*contd.*

Date of flowering	No. of days
December 24	70·7
December 25	72·1
December 26	70·2
December 27	70·7
December 28 and after	70·0

Selection II.

Date of flowering	No. of days
November 22 and before	69·1
November 23	67·6
November 24	67·5
November 25	70·0
November 26	70·6
November 27	71·3
November 28	69·7
November 29	70·0
November 30	70·2
December 1	70·1
December 2	70·0
December 3	69·5
December 4	69·6
December 5	69·6
December 6	68·8
December 7	70·1
December 8	70·5
December 9	69·7
December 10	68·3
December 11	70·0
December 12	69·6
December 13	68·0
December 14	67·3
December 15	69·5
December 16	69·3
December 17	70·5
December 18	70·0
December 19	69·8
December 20	69·8
December 21	68·0
December 22	68·9
December 23	68·9
December 24	68·1
December 25	68·5
December 26	69·2
December 27	67·8
December 28 and after	67·1

APPENDIX No. II.

Average number of days of maturity of bolls, 1924-25 (Broach).

Selection II.

Date of flowering	No. of days
November 14 and before	66
November 15	65·7
November 16	65·7
November 17	68·8
November 18	68·5
November 19	69·9
November 20	71·0
November 21	69·1
November 22	70·2
November 23	70·6
November 24	72·0
November 25	72·0
November 26	71·5
November 27	73·3
November 28	73·2
November 29	72·7
November 30	73·0
December 1	72·4
December 2	71·3
December 3	71·5
December 4	71·9
December 5	73·0
December 6	73·0
December 7	73·8
December 8	73·3
December 9 and after	72·7

B. D-4.

Date of flowering	No. of days
November 14 and before	69·7
November 15	72·0
November 16	73·2
November 17	74·0
November 18	72·7
November 19	73·8
November 20	74·2
November 21	71·8
November 22	73·6
November 23	74·6

B. D.-4—*contd.*

Date of flowering	No. of days
November 24	74·3
November 25	76·2
November 26	77·6
November 27	77·4
November 28	77·8
November 29	77·2
November 30	78·6
December 1	78·2
December 2	77·2
December 3	77·7
December 4	78·2
December 5	78·1
December 6	78·8
December 7	78·5
December 8	78·4
December 9 and after	76·6

I-A CYLINDRICAL BOLL.

Date of flowering	No. of days
November 14 and before	76·7
November 15	78·9
November 16	78·8
November 17	77·6
November 18	76·9
November 19	77·9
November 20	77·0
November 21	77·4
November 22	76·7
November 23	76·9
November 24	77·9
November 25	77·2
November 26	78·3
November 27	78·3
November 28	78·0
November 29	78·3
November 30	79·0
December 1	77·7
December 2	78·1
December 3	79·4
December 4	79·4
December 5	79·5
December 6	78·8
December 7	79·1
December 8	79·8
December 9 and after	78·6

B. D-6.

Date of flowering	No. of days
November 14 and before	67·5
November 15	65·5
November 16	69·0
November 17	71·8
November 18	69·5
November 19	70·7
November 20	68·7
November 21	71·1
November 22	70·7
November 23	71·0
November 24	71·9
November 25	72·0
November 26	72·3
November 27	72·5
November 28	73·2
November 29	71·5
November 30	72·5
December 1	71·7
December 2	73·1
December 3	72·2
December 4	72·5
December 5	71·9
December 6	72·2
December 7	71·7
December 8	72·8
December 9 and after	72·3

APPENDIX III.

Correlation frequency of lint weight and seed weight from boll to boll.

SELECTION II AT SURAT.

Seed weight in milligrams.

Lint weight per seed in milligrams.	26	30	34	38	42	46	50	54	58	62	66	70	74	78	82	86	90
9	2																
11		2	1					1									
13		1	1	1	1												
15			1		1												
17				3	2	1				1							
19				1	3	2	1		1		*1*						
21					1	1	1	4		2	*1*	*2*			*1*		
23					1	1	4	3	2		2^2				*1*	*1*	
25						5	6	4	4	3	4	2	*2*		*1*		
27					1	3	8	13	15	9	7	3	*1*	*1*	*1*		*2*
29					1	1	2	17	17	22	13	8	*1*		*1*	*1*	
31						1	8	31	38	38	22	12	8	*1*	*2*	*1*	
33						1	2	28	53	50	45	19	10	*1*	*1*	*1*	
35							3	25	43	70	52	26	17	5	*3*	1	
37							2	12	47	58	65	32	20	4	3	2	1
39							1	7	18	53	55	44	32	18	7		
41								1	10	22	44	39	22	13	3		
43								1		6	13	22	16	7	3		1
45									2	6	8	9	14	9	3		
47										2	1	2	3	3	2		
49												1	1	3			
51														1			

Italic figures show number of bolls with very few seeds.

Correlation frequency of lint weight and seed weight from boll to boll.

SELECTION II AT BROACH.

Seed weight in milligrams.

Lint weight per seed in milligrams.	30	34	38	42	46	50	54	58	62	66	70	74	78	82	86	
13		3														
15	4		1	1				1								
17		2	4	1			1			*1*						
19			3	2	4	1										
21			2	9	6	2	2	1								
23				7	5	7	2	2	3^{2}	*5*	3^{2}	*1*				
25				2	11	14	5	3	5	3^{3}	*1*					
27					2	16	21	7	11	5^{3}	3^{3}	3^{1}	*1*			
29				1	3	15	21	23	11	17	7^{3}	6^{4}	*1*			
31						10	21	32	29	22	5	9	*2*	*1*	*2*	
33						8	16	33	41	27	18	7	3^{2}	*1*		
35						2	9	23	28	30	20	11	2			
37						2	6	12	22	36	22	9	6	1	1	
39								3	11	13	16	12	8	4		
41									6	10	10	6	4	1		
43										4	3	3	1			
45										1	3	1	1			
47												2				

Italic figures show number of bolls with very few seeds.

APPENDIX IV.

Average number of seeds per boll, 1924-25.

SELECTION III.

Date of flowering	No. of seeds
November 14 and before	22·1
November 14	20·6
November 15	22·8
November 16	19·6
November 17	21·2
November 18	19·3
November 19	18·9
November 20	20·1
November 21	20·9
November 22	21·4
November 23	22·7
November 24	20·1
November 25	21·8
November 26	19·1
November 27	18·0
November 28	17·1
November 29	17·4
November 30	18·3
December 1	16·1
December 2	20·6
December 3	16·8
December 4	18·3
December 5	20·6
December 6	21·1
December 7	19·8
December 8	19·9
December 9 and after	20·7
AVERAGE	19·9

F

I-A CYLINDRICAL BOLL (BROACH).

Date of flowering	No. of seeds
November 14	20·1
November 15	19·6
November 16	18·3
November 17	18·6
November 18	19·2
November 19	18·8
November 20	20·2
November 21	20·2
November 22	20·4
November 23	21·1
November 24	20·5
November 25	19·9
November 26	20·0
November 27	19·1
November 28	19·8
November 29	19·3
November 30	18·8
December 1	19·5
December 2	18·9
December 3	20·1
December 4	19·2
December 5	19·2
December 6	19·6
December 7	20·9
December 8	19·1
December 9 and after	19·5
AVERAGE	19·6

SELECTION II (SURAT).

Date of flowering	No. of seeds
November 22	19·6
November 23	21·4
November 24	21·9
November 25	20·9
November 26	19·8
November 27	18·7
November 28	19·6
November 29	20·4
November 30	20·6
December 1	20·6
December 2	20·5
December 3	20·0
December 4	19·2
December 5	20·3
December 6	19·6
December 7	18·8
December 8	19·0
December 9	19·0
December 10	19·0
December 11	19·6
December 12	19·1
December 13	19·1
December 14	19·8
December 15	20·3
December 16	19·4
December 17	20·2
December 18	20·1
December 19	20·1
December 20	19·1
December 21	19·5
December 22	19·1
December 23	19·0
December 24	19·0
December 25	18·0
December 26 and after	17·4
	17·3
AVERAGE	19·5

MGIPC—M—IV-2-71—22-5-1928—650.

CONTENTS

PLATES

STUDIES IN THE SHEDDING OF MANGO FLOWERS AND FRUITS, PART I.

BY

P. V. WAGLE, M.Ag.

(Received for publication on 12th September 1927.)

Introduction.

The mango is the premier fruit crop of the Bombay Presidency and in certain districts, notably in Ratnagiri and Thana, it forms the basis of considerable commercialised fruit industry. The whole status of the industry is rendered very uncertain, however, by the very great loss of flowers and fruit which occurs annually through shedding. The loss is always very great, but the variation in different years is enough to make the production in some seasons not more than a quarter to a third of that in others, while in each year, in one area or another almost the whole of the crop is lost.

This loss of crop through shedding of flowers and fruits, on trees whose flowers appear normally, is known locally as 'mango blight' and has been attributed to a multitude of causes. In popular estimation it is connected with the occurrence of rainy or cloudy weather or of excessive dew at the time of flowering and formation of fruits[1]. Its partial connection with certain species of *jassid* hoppers (*Idiocerus*) has been considered as proved[2, 3, 4]. The frequent occurrence of mildew on the inflorescences when shedding is going on has been noticed, though the connection of this fungus with the shedding itself has hardly been hitherto demonstrated. Other workers[5] have connected the loss with the infertility of a large proportion of the pollen, as a result of vegetative propagation through many generations; and, finally, Popenoe[6, 7] has concluded that the problem is a physiological one connected with nutritional conditions, as influenced by changes in soil moisture and food supply, principally the former.

The matter is of sufficient importance to warrant a study of the whole question of the shedding of mango flowers and fruits on a somewhat broader basis than has

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[1] McMurram, S. M. The Anthracnose of the Mango in Florida. *U. S. Dept. Agri. Bull.* 52 (1914).
[2] Ballard, E. Mango hopper control experiments. *Agri. jour. of India*, Vol. X (1915).
[3] Husain, M. A., and Pruthi, H. S. Some experiments to control mango hoppers. *Rept. Proc. Fourth Ent. Meeting, Pusa* (1921).
[4] Note on Mango hopper and mildew. *Jour. Mysore Agri. and Expt. Union*, Vol. III (1921).
[5] Jivan Rao, P. S. Pollen sterility in relation to vegetative propagation. *Jour. Madras Agri. Students' Union*, Vol. XI, Nos. 9 and 10 (1923).
[6] Popenoe, W. The pollination of Mango. *U. S. Dept. Agri. Bull.* 542 (1917).
[7] Popenoe, W. Manual of Tropical and Sub-Tropical Fruits (1920).

been hitherto done, and the author has had the opportunity during the last two years (thanks to funds provided by the Sir Sassoon David Trustees) to commence the investigation of the problem in the centre of the most important mango producing area of the Bombay Presidency, Ratnagiri in the Konkan. The present memoir brings together most of the data hitherto obtained.

Mango inflorescence.

The inflorescence of the mango has been several times described in detail in recent years [1], but the main point of importance in the present discussion is the fact that by far the largest proportion of the flowers in the inflorescence are staminate or male. The inflorescence, in fact, consists of both hermaphrodite or complete flowers and staminate or male flowers, and in the variety most largely and, indeed, almost exclusively cultivated in Western India on a commercial basis,—the Alphonso or *Hapuz* variety,—the proportion of complete flowers is very small. As all the author's experiments have been made with this variety, the normal position in this case may be indicated.

A very cursory examination of the inflorescences even of a single tree, and even when they are produced at the same time of year, shows that the proportion of male to complete flowers is very variable indeed. Taking the season as a whole at Ratnagiri, a study of seventy-three different inflorescences showed in 1925-26 a variation in the proportion of complete flowers from 2 to 55 per cent. In 1926-27 an examination of 319 flower heads showed a variation of from 0 to 30 per cent. of complete flowers. We have now to study the fact of this extraordinary variation and to attempt to correlate it with other factors in determining the character of the inflorescence.

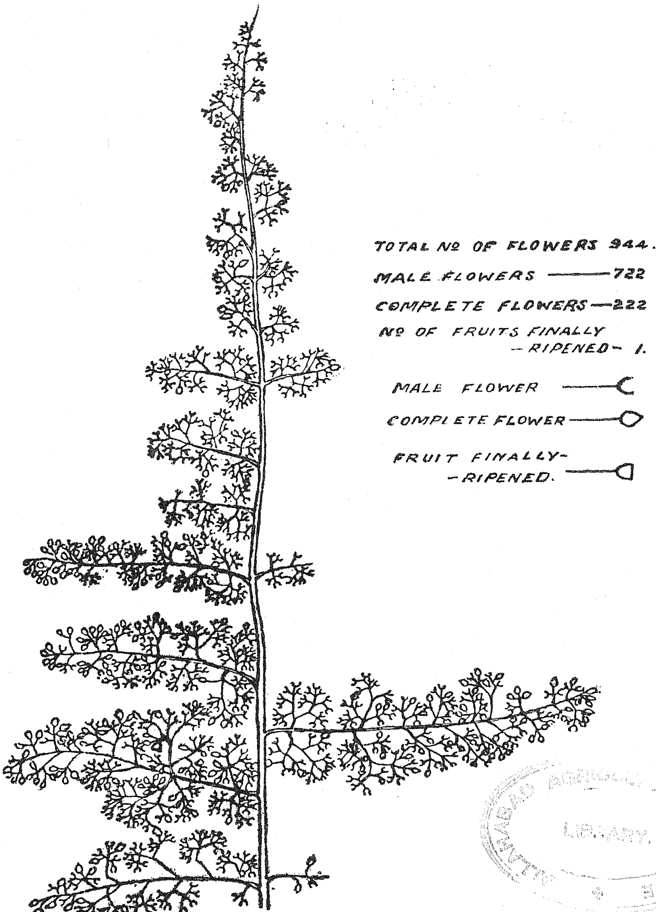
From the results of 1925-26, details are available with regard to forty inflorescences occurring on thirteen trees. A full statement will be found in Appendix I. But the figures show that out of forty cases—

2 cases gave under 5 per cent. of complete flowers.
6 cases gave from 5 to 10 per cent. complete flowers.
10 cases gave from 10 to 20 ,, ,, ,,
7 cases gave from 20 to 30 ,, ,, ,,
8 cases gave from 30 to 40 ,, ,, ,,
5 cases gave from 40 to 50 ,, ,, ,,
2 cases gave over 50 per cent. complete flowers.

In 1926-27, the proportion of complete flowers was far lower than in the previous year, and an examination of 319 inflorescences from seventeen trees gave the following figures—

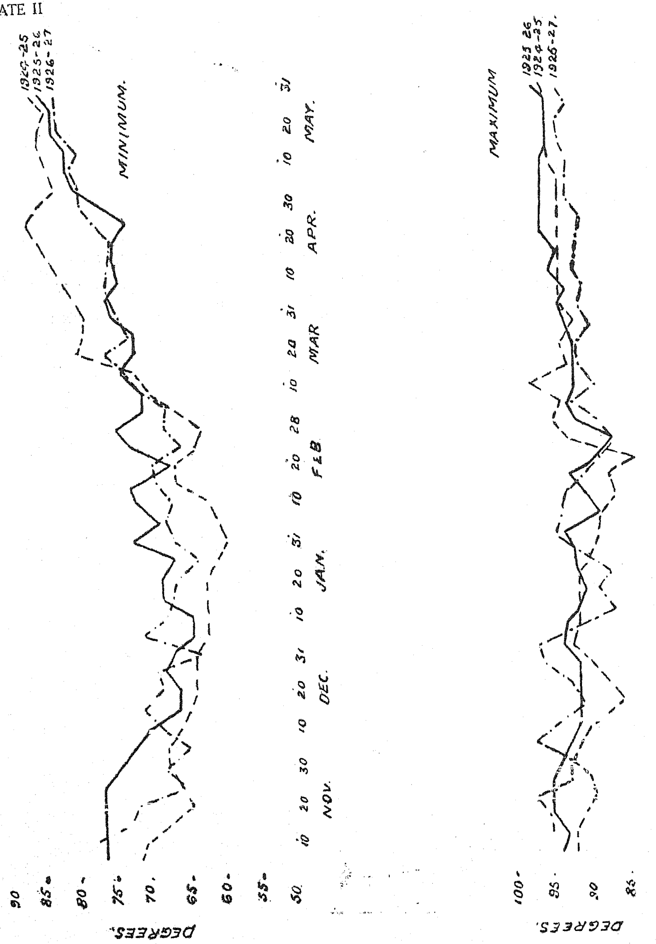
265 cases gave under 5 per cent. of complete flowers.
27 cases gave from 5 to 10 per cent. of complete flowers.
21 cases gave from 10 to 20 ,, ,, ,,
4 cases gave from 20 to 30 ,, ,, ,,
2 cases gave from 30 to 40 ,, ,, ,,
No cases gave over 40 per cent. of complete flowers.

[1] Burns, W., and Prayag, S. H. Notes on the Infloresence and Flower of the Mango Tree. *Poona Agri. Coll. Magazine*, Vol. II (1911) p. 226.
Popenoe, W. The Pollination of the Mango. *U. S. Dept. Agri. Bull.* 542 (1917).



Mango inflorescence showing sex and fate of every flower.

PLATE II



Temperature Graphs at Ratnagiri 1924—27.

It is difficult to account for the very great difference between the two seasons, and it would seem to indicate some very deep distinction in the weather characters at the time the inflorescences were forming. But this deep distinction is not easily detected from the records.

Considered as a fruit producing season, the year 1925-26 was very unsatisfactory, being a year following an extraordinarily abundant crop. The flowering was very late and scarce, and only started early in January in Ratnagiri instead of, as usual, in November. The flowering this year was in fair flushes, which were not, however, very distinct. The first and the largest took place in the first week in January, and the height of each of the others followed at an interval of about a month. Except early in January there was no cold weather, in contrast to the previous year when long continued cold weather occurred. Plate II shows this difference clearly. There was rain in November and January, which was exceptional but no rain from February onward and little dew.

In 1926-27 the season was on the whole a good one. The flowering took place in three fairly distinct flushes in November to December, early January and early February. There was no rain during the flowering season, but much dew during February and March.

The following Table shows the rainfall, month by month, in the three seasons ending 1927.

TABLE I.

Rainfall at Ratnagiri, 1924-27.

—	1924	1925	1926	1927
	In.	In.	In.	In.
June	29·28	29·24	20·98	..
July	39·31	14·24	33·84	..
August	14·65	21·17	49·67	..
September	8·16	4·26	12·90	..
October	2·12	1·87	1·37	..
November	*nil.*	1·15	*nil.*	..
December	..	*nil.*	*nil.*	..
January	..	..	0·65	*nil.*
February	..	..	*nil*	*nil*
March	..	..	..	*nil.*
April	..	..	..	0·04
May	..	1·3	..	0·42

It would seem from this that the large proportion of complete flowers in the inflorescences in 1925-26 accompanied an unusually small amount of flowering. In 1926-27, when flowering was generally much more profuse, the proportion of complete flowers, capable of producing fruits, was very much lower. There seems some evidence that the absence of cold weather discourages flowering, but it is by no means conclusive.

Two points of interest now arise. Is the variation in the proportion of complete flowers during the same season due to (1) the individuality of trees, or, in other words, is the variation on one tree less than the general variation above noted and (2) the time of the season when the inflorescences are formed, or, in other words, is the proportion of complete flowers different in the first, second and third flushes?

The second point may be first considered, and in this matter data can only be presented for 1926-27. But here the proportion of *complete* flowers in the inflorescences of the different flushes found by examination of a large number of such inflorescences was as follows :—

TABLE II.

Proportion of complete flowers in different flushes 1926-27.

Flush	Number of inflorescences examined	Range of variation	Average
		per cent	per cent.
1st flush	159	0 to 15·1	1·5
2nd flush	80	0 to 34·9	7·0
3rd flush	80	0 to 30·2	3·4

The proportion of flower heads with different percentages of complete flowers in the inflorescences is shown in the following table.

TABLE III.

Proportion of flower heads with different percentages of complete flowers, 1926-27.

Percentages of complete flowers	NUMBER OF INDIVIDUALS		
	First flush	Second flush	Third flush
0·0 to 0·25	27		
0·25 to 0·5	14	5	21
0·5 to 1·0	31		
1·0 to 1·5	31		
		19	13
1·5 to 2·0	15		
2·0 to 2·5	15		
2·5 to 3·0	9	15	27
3·0 to 4·0	7		
4·0 to 6·0	6	12	5
6·0 to 10·0		9	9
10·0 to 14·0	4	10	4
14·0 to 20·0		6	1
20·0 and above	..	4	..
	159	80	80

These figures would suggest that the proportion of complete flowers is likely to be higher in the second flush, that is to say, in the middle of the flowering season,

than in the first and third. This conclusion may be considered, however, as very tentative. It may be noted that the inflorescences of the first flush were very large, much larger than the later ones. Thus the average number of flowers (complete and staminate together) in the flowerheads of the first flush was 6,191 (from a study of 20 flower heads), in those of the second flush was 2,435 (from a study of 10 flower heads), and in those of the third flush was 2,689 (again from a study of 10 flower heads). It is, therefore, possible that in larger flowerheads the proportion is likely to be low irrespective of the flush, and that the low proportion in the first flush is likely to result because the flowerheads of that flush are usually large. The average proportion of complete flowers in inflorescences of different sizes, taken from all the flushes, was as follows in 1926-27.

Total number of flowers per inflorescence	Average proportion of complete flowers
Below 2,000	5·34 per cent
2,000 to 4,000	3·47 ,,
4,000 to 6,000	2·40 ,,
6,000 to 8,000	1·53 ,,
Over 8,000	1·54 ,,

These figures certainly suggest that the large flowerheads *do* have a smaller proportion of complete flowers, and it may be noted, in passing, that this agrees with the opinion of the mango growers, who look upon large inflorescences as largely barren.

As regards the individuality of the different trees in the matter of the proportion of complete flowers we have records from a number of flowerheads on seventeen trees. Eight of these are from trees which chiefly flowered in the first flush, and nine from trees which gave its principal crop in the second and third flushes. The following are the results tree by tree.

TABLE IV.

Proportion of complete flowers on different trees.

Number of trees	Number of flowers examined	Percentage of complete flowers	
		Range	Average
		Per cent.	Per cent.
I. Main flowering in 1st flush.			
1	48	0·0 to 4·0	1·0
2	8	0·1 to 3·1	0·9
3	24	0·0 to 2·7	1·2
4	16	0·5 to 18·2	5·5
5	16	0·0 to 2·1	0·8
6	32	0·0 to 29·3	3·9
7	15	0·4 to 7·3	2·5
8	24	0·4 to 26·3	5·5

TABLE IV—*contd.*

Number of trees	Number of flower examined	Percentage of complete flowers	
		Range	Average
II. Main flowering in 2nd and 3rd flush.			
		per cent.	per cent.
9	32	0·0 to 7·4	1·7
10	16	0·1 to 27·5	6·2
11	16	1·0 to 6·8	3·4
12	16	0·0 to 10·8	3·6
13	16	0·0 to 34·9	4·0
14	16	1·0 to 30·2	10·3
15	8	1·5 to 11·1	6·7
16	8	0·0 to 8·0	2·1
17	8	0·4 to 4·3	2·7

When we compare these figures for individual trees with the general range for all flowers of each flush taken together (Table III) it is seen that the range on one tree may be nearly as great as for the whole of the inflorescences on a number of trees and hence it cannot be considered that a large proportion of complete flowers or *vice versa* is characteristic of particular trees.

The number of complete flowers in any inflorescence represents the maximum possible fruit production. But the *actual* fruit production is, under any circumstances, very small in relation to the number of such flowers. In country seedling mangoes the number of fruits may go to eight or ten per inflorescence, but in the Alphonso variety, the maximum the author has ever seen is five ripe fruits per inflorescence. This number is, however, very rare. Four fruits per flower head is uncommon, and three not very frequent. Most inflorescences produce not more than one or two. And yet the proportion of flowers fertilised is very large and the number of fruits actually formed is from four to twelve times as many as the number that finally mature. The actual figures from a detailed study of seven flowerheads 1925-26 and of twenty flowerheads in 1926-27 gave the following figures.

TABLE V.

Proportion of complete flowers shed in different stages.

—	1925-26	1926-27
Flowerheads examined	7	20
Total complete flowers in these heads	1,558	2,151
	Per cent.	Per cent.
Proportion shed before fertilisation	38·4	53·5
Proportion shed just after fertilisation	56·4	41·3
Proportion shed before fruit is of the size of a marble	3·6	4·0
Proportion shed at later stage	0·8	0·9
Proportion forming mature fruits	0·8	0·3

It is to the study of the causes of this enormous amount of shedding that the remainder of the present memoir will be devoted.

PLAN AND METHOD OF STUDY.

Starting with the idea that the shedding of flowers and fruits might be due either wholly or partly to (1) mango *jassid* hoppers, (2) mildew, (3) rainy and cloudy weather, (4) excessive dew and (5) lack of available plant food, observations were made in order to find out the relation of these different causes to the phenomenon under study and experiments were planned to examine the effect of each of these individual factor separately. More attention has been paid to the first two factors, namely, mildew and *jassid* hoppers. For studying the nature of the flowers, they were carefully examined and a record of the sex of the flowers in all the flowerheads has been kept. For the study of *Jassid* hoppers and mildew, seven sets of flowerheads were treated as described below and their behaviour noted from time to time. Ten flowerheads only could be treated during the first year and forty during the second year in each set of the experiment. Flowerheads for each method of treatment were in most of the cases selected from the same tree and even from the same branch.

1. Under open conditions, with no treatment.
2. Under open conditions and sprayed with Fish oil rosin soap to kill hoppers; but not sprayed for mildew.
3. Under open conditions, and sprayed against mildew with Bordeaux mixture; but not sprayed against hoppers.
4. Under open conditions and sprayed with a mixture of Fish oil soap and Bordeaux mixture to destroy both hoppers and mildew.

5. Bagged to exclude hoppers and no other treatment.
6. Bagged to exclude hoppers and inoculated with hoppers.
7. Bagged to exclude hoppers and inoculated with mildew.

For studying the question as to whether the loss of flowers and fruits is brought on by insufficiency of plant food or water, manuring and irrigation experiments were also conducted and these plants were also kept under observation.

With a view to find out what happens to the numerous flowers, appearing on a flowerhead, a large number were kept under close observation. The shed flowers and fruits from all the flowerheads under treatment were collected every alternate day during the first year and once every week during the second year, from the bags in the case of the bagged flowerheads, and in big tin funnels, provided with cloth bags at the bottom in the case of the open flowerheads. After a careful examination under a lens, the flowers and fruits were separated and classified according to the size and cause so far as this could be made out from the external symptoms. Those for which no explanation could be given were classed as unknown.

Besides weekly notes were kept after careful inspection of all the flowerheads as regards the extent of infection of hoppers, mildew, etc., and also the setting of fruit. These were compared from time to time with the actual shedding from the different causes. The results of various methods of treatment will be detailed later.

Details of the method of treatment. The work of the first year having started very late, flowerheads of the first flush could not be taken up for treatment. But of the ten taken, five were from the second and five from the third flush. In the second year, out of the forty flowerheads, twenty were from the first flush, ten from the second and ten from the third.

Sprayings of Bordeaux mixture (5·5·50) and Fish oil rosin soap solution (1 per cent. strength of the soap manufactured by the Government Soap Factory, Calicut, was used during the first year, while during the second year ½ per cent. strength of the soap prepared by the Dharamsi Morarji Chemical Co., Ambarnath was found quite effective) and a combined spray of both in the same proportions were given during the season to the respective series according to the requirements till the fruits had developed. The dates of the sprayings are as under :—

TABLE VI.

Dates of spraying mango trees.

1925-26				1926-27					
No.	Second flush	No.	Third flush	No.	First flush	No.	Second flush	No.	Third flush
1	25th Feb.	1	3rd March	1	16th Dec. .	1	13th Jan.	1	5th Feb.
2	8th March	2	17th ,,	2	21st ,, .	2	21st ,, .	2	11th ,,
3	17th ,, .	3	24th ,, .	3	27th ,, .	3	31st ,, .	3	21st ,,
4	24th ,, .	4	8th April .	4	7th Jan. .	4	15th Feb. .	4	3rd March
5	8th April. .	5	16th ,, .	5	22nd ,, .	5	3rd March .	5	17th ,,
6	16th ,,								

Mildew was inocu'ated first by preparing a mixture of spores obtained from scraping already affected flowerheads in water and applying the same to the healthy ones with a brush. Later on it was found that inoculations could be done more conveniently and effectively by vigorously shaking affected flowerheads just near the healthy ones. The dates of the inoculations are given below :—

TABLE VII.

Dates of mildew inoculations.

1925-26		1926-27		
Second flush	Third flush	First flush	Second flush	Third flush
24th February .	3rd March .	30th December to 1st January.	16th and 17th January.	11th February.

The hopper inoculations were carried out by letting small nymphs of hoppers of the species (*Idiocerus niveosparsus*) the predominent species found in the Konkan on the flowerhead and repeating the inoculation from time to time as they flew off after hatching into adults. The details of the inoculation; are as under :—

TABLE VIII.

Dates of inoculations with Jassid *hoppers.*

1925-26				1926-27					
SECOND FLUSH		THIRD FLUSH		FIRST FLUSH		SECOND FLUSH		THIRD FLUSH	
Date	No. of nymphs	Date	No. of nymphs	Date	No. of nymphs	Date	No. of nymphs	Date	No. of nymphs
23-2-26 .	10	7-3-26 .	25	28-12-26 to 1-1-27	25	18-1-27 .	25	22-1-27 .	25
27-2-26 .	5	10-3-26 .	25	4-1-27 to 6-1-27	25	24-1-27 .	25	28-1-27 .	25
8-3-26 .	5	18-3-26 .	50	10-1-27 to 12-1-27	25	25-1-27 .	25	31-1-27 .	25
12-3-26 .	10	26-3-26 .	50	15-1-27 .	25	26-1-27 .	25	3-2-27 .	25
13-3-26 .	10	31-3-26 .	20	24-1-27 to 26-1-27	25	29-1-27 .	25	5-2-27 .	25
14-3-26 .	10	1-4-26 .	20	29-1-27 .	25	31-1-27 .	25	10-2-27 .	25
26-3 26 .	25	2-4-26 .	10	2-2-27 .	25	3-2-27 .	25	14-2-27 .	25
31-3-26 .	10	..	..	9-2-27 .	25	9-2-27 .	25	21-2-27 .	25
1-4-26 .	10	..	..	14-2-27 .	25	14-2-27 .	25	25-2-27 .	25
2-4-26 .	5	..	..	19-2-27 .	25	..	..	3-3-27 .	25
								8-3-27 .	25
TOTAL .	100		200		250		225		275

Further, some trees were either wholly or partly sprayed with Bordeaux mixture, Fish oil soap solution and a combined spray of both Bordeaux mixture and Fish oil soap to destroy the natural mildew and hoppers. Control was kept on the same tree or on the adjacent one. The number of flowerheads that appeared on each of these trees was counted, so also the number of fruits harvested.

Certain manuring experiments were conducted to see if the blight be due to want of food supply. The manures were given in two doses in February and March during the first year and in September and December during the second year. The details of the manures is given below. The quantities are per tree.

TABLE IX.

Manurial treatments used.

1925-26				1926-27			
1ST DOSE		2ND DOSE		1ST DOSE		2ND DOSE	
Name of manure	Quantity	Name of manure	Quantity	Name of manure	Quantity	Name of manure	Quantity
	lb.		lb.		lb.		lb.
Sulphate of ammonia	3	Sulphate of ammonia.	2	(1) Bone super-phosphate.	6	(1) Bone super-phosphate.	4
Bone super-phosphate.	6	Bone super phosphate.	4	(2) Bone super-phosphate and	6	(2) Bone super-phate and	4
				nitrate of soda.	4	nitrate of soda.	3
				(3) Bone super-phosphate, nitrate	6	(3) Bone super-phosphate, nitrate	4
				of soda and	4	of soda and	3
				sulphate of potash.	4	sulphate of potash.	3

The trees were irrigated with nearly one acre-inch of water every week from the time of the application of the manure to the middle of April; other trees being watered for comparison. A record of the flowerheads and the number of fruits was kept in each case.

PHENOMENON OF FLOWER AND FRUIT SHEDDING.

Figures have already been given which indicate, for a number of complete flowerheads, the actual loss by shedding at different stages of the development of the inflorescence. These show that in the two years 38·4 and 53·5 per cent. respectively of the complete flowers shed before fertilisation, and 56·4 and 41·3 per cent. almost immediately after fertilization before the fruit was the size of a small marble. Thus in both years 94·8 per cent. were shed in these early stages, leaving only 5·2 per cent. of the complete flowers to develop fruits which even reached the small size indicated.

It is now necessary to study this phenomenon in more detail.

The shedding of the unfertilized flowers generally begins on the fourth day after the opening of the flower and of the fertilised ones after a week or ten days. If the shed flowers and fruit are classified week by week, it is noticed that the shedding increases upto the fourth week and then it gradually falls off. This can be seen from the accompanying table in which figures are given calculated for ten thousand complete flowers. The figures are only given for the third flush of 1925-26, when there were no *jassid* hoppers and little mildew and for the first flush of 1926-27 when there were no hoppers and practically no mildew was detected.

TABLE X.

Flowers shed at different stages.

1925-26				3rd Flush				1926-27				1st Flush			
Week ending	Complete flowers before fertilisation	Fruit within 0·2 cm.	Fruit from 0·2 to 0·4 cm.	Fruit from 0·4 to 0·8 cm.	Fruit from 0·8 to 1·5 cm.	Fruit from 1·5 to 3·0 cm.	Fruit above 3·0 cm.	Week ending	Complete flowers before fertilisation	Fruit within 0·2 cm.	Fruit from 0·2 to 0·4 cm.	Fruit from 0·4 to 0·8 cm.	Fruit from 0·8 to 1·5 cm.	Fruit from 1·5 to 3·0 cm.	Fruit above 3 cm.
13-3-26	375·3	242·8	66·2	..	..	..	..	15-1-27	241·74	55·78	27·88	..	..	..	..
20-3-26	662·3	485·6	176·6	22·1	..	..	..	22-1-27	381·21	213·85	120·87	27·88	..	..	..
27-3-26	838·9	353·2	441·5	110·4	22·1	..	..	29-1-27	404·46	167·36	176·66	18·59	..	..	..
3-4-26	905·1	1,258·3	662·3	110·4	..	..	..	5-2-27	1,143·65	543·93	478·84	27·88	..	..	..
10-4-26	198·7	309·1	66·2	22·1	..	..	..	12-2-27	822·87	460·25	232·45	51·13	23·24	..	..
17-4-26	198·7	132·5	110·4	22·1	66·2	..	..	19-2-27	748·48	320·78	278·94	41·84	23·24	4·66	9·29
24-4-26	331·1	154·5	154·5	..	..	44·2	..	26-2-27	567·17	278·94	264·99	37·18	74·36	37·36	..
1-5-26	397·4	662·3	331·1	..	..	66·2	..	5-3-27	260·34	134·82	60·43	18·59	41·84	18·59	4·66
8-5-26	..	..	..	..	..	..	..	12-3-27	776·38	223·15	88·33	18·59	..	4·66	..
								19-3-37	..	..	..	..	..	..	4·66
								26-3-27	..	..	..	..	..	..	4·66
								16-4-27	..	..	..	..	..	..	4·66
Total .	3,907·3	3,598·2	2,008·9	287·0	88·3	110·4	..	Total .	5,346·30	2,398·86	1,729·39	241·68	162·68	65·27	27·93

In order to form an idea of the age of the shed fruit, measurements of a number of growing fruit were kept from the time of the fertilization to the time of the harvest. It was observed that the fruits which are going to shed, gradually slow down in growth a few days before shedding and ultimately stop growth altogether, dry up and fall. The following may roughly be taken as the rate of growth of a healthy fruit.

TABLE XI.

Rate of growth of a healthy mango fruit.

Age in days	Size in cm.	Average rate of growth per day	REMARKS
1 . . .	0·1	....	Unfertilised.
5 . .	0·2	0·025	Fertilised.
9 . . .	0·4	0·05	
17 . .	0·8	0·05	
25 . . .	1·5	0·08	
37 . . .	3·0	0·13	
55 . . .	5·5	0·14	
81 . . .	7·5	0·08	Mature fruit.

With a view to ascertain the immediate causes of shedding so far as could be detected from the external symptoms, the shed forms were subjected to a careful examination with a hand lens and certain obvious symptoms such as mildew, black-spots, etc., were noted. Those which could not be accounted for were classed as unknown. The following table gives the results of such a study for the three flushes on untreated trees in 1926-27.

TABLE XII.

External symptoms of shed flowers and fruits.

Flush	Total number of complete flowers	ACTUAL			PERCENTAGE		
		with mildew	with black spots	Un-known	With mildew	With black spots	Un-known
First . .	2,151	35	40	2,070	1·62	1·85	96·22
Second . .	1,264	142	11	1,108	11·23	0·87	87·65
Third . .	852	382	7	462	44·83	0·82	54·22

It will be seen from this that the shedding of a very large percentage cannot be accounted for by any obvious external appearance. There is a large percentage of mildew affected forms in the third flush only when there was severe mildew attack. The mildew went on increasing from flush to flush. Nothing has been so far ascertained as to the nature of the black spots on the very very small fruits which appeared in certain cases to be associated with this shedding. The nature and action of the mildew will be considered later.

In planning the experiments which have already been indicated, it was originally supposed that the treatments to be used would themselves exert little or no direct effect on the falling of the flowers. This has proved not to be the case, and the study of the bagged flower heads in particular has been very instructive in this connection.

Taking flowerheads which were enclosed in muslin bags before the flowers opened, the loss was very much greater than with flowers of the same trees exposed to the air. The number of flowerheads examined was 7 and 10 respectively in the unbagged and bagged series in 1925-26 and 20 in both cases in 1926-27.

TABLE XIII.

Comparison of shedding in bagged and unbagged flowerheads.

—	1925-26		1926-27	
	Unbagged	Bagged	Unbagged	Bagged
Number of complete flowers opened	1,558	2,241	2,151	650
Percentage shed before fertilisation	38·4	54·0	53·5	87·6
Percentage shed after fertilization	60·8	45·8	46·3	12·3
Percentage of fruits ripened	0·8	0·2	0·2	0·1

These figures show how bagging interferes considerably with fertilization, raising the percentage of complete flowers, which were never fertilized from 38·4 to 54·0 in 1925-26 and from 53·5 to 87·6 per cent. in 1926-27. The question of the activity of the wind and of insects on the pollination of the mango flower is one which has been much discussed, and in the present case the effect of the wind is reduced and that of insects wholly excluded.

Of the flowers which are fertilized, these figures gave no satisfactory evidence as to whether the bagging, that is to say, the absence of air movement and of insects causes shedding. In 1925-26, the proportion of flowers which fell after fertilization was larger in bagged flowers than in the open. In 1926-27 the opposite was the case. The actual proportion of *fertilised* flowers which gave mature fruits in 1925-26 was 1·25 per cent. in the unbagged heads and 0·5 per cent. in the bagged ones. In 1926-27 the corresponding figures were 0·6 per cent. in the open inflorescences and 1·25 per cent. in those contained in muslin bags. There is, therefore, no evidence

that absence of air movement or of insects has any special disadvantage, after fertilization has been achieved.

The effect of spraying the flowering trees with Bordeaux mixture, with Fish oil soap solution and with a combination of these two was decidedly interesting. We can, in one case, determine the effect of these sprays *themselves*, for in the 1st flush of flowers in 1926-27, there was practically a total absence of *jassid* hoppers and of mildew. The results, therefore, show the effect of the sprays on the flowers themseves, the sprays being applied on dates as follows, while the flush was going on :—(1) December 16, 1926 (2) December 21, 1926, (3) December 27, 1926, (4) January 7, 1927 (5) January 22, 1927.

The actual results are shown in the following table, the figures being from twenty heads in each case :—

TABLE XIV.

Effect of sprays on shedding in mango flowers.

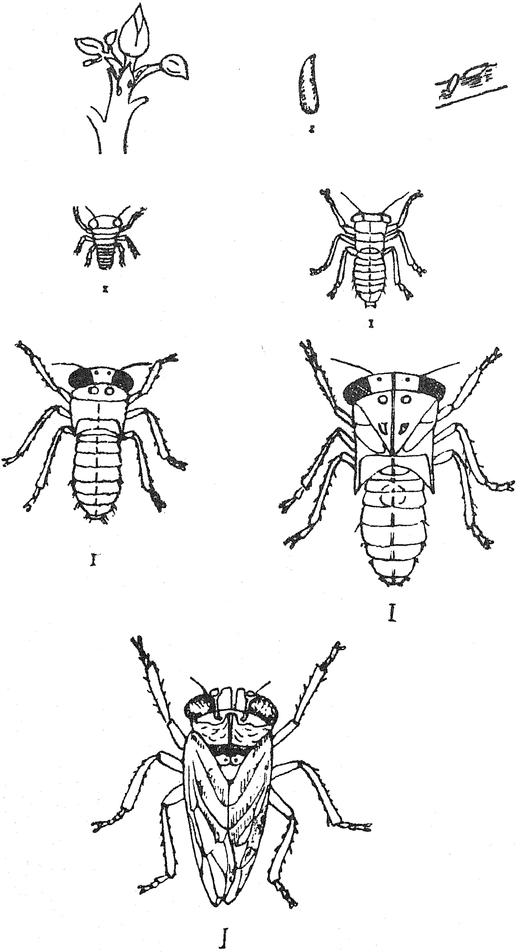
Treatment	Complete flowers examined	Proportion shed (a) Before fertilisation	Proportion shed (b) After fertilisation	Proportion of ripe fruit
		Per cent.	Per cent.	Per cent.
1. Without treatment	2,151	53·5	46·3	0·28
2. Sprayed with Bordeaux mixture	2,785	65·2	34·5	0·32
3. Sprayed with Fish oil rosin soap	2,190	58·6	41·1	0·27
4. Combined spray of (2) and (3)*	1,173	53·3	46·5	0·26

These figures show that the number of fruits ripened for a given number of complete flowers is hardly affected by the spraying treatment. If anything the Bordeaux mixture seems to have a somewhat beneficial effect, and leads to the ripening of a slightly larger number of fruits. On the other hand, when this spray is used, there is a distinctly larger number of flowers which shed without fertilisation. The other sprays seem to have had little effect at any stage of the development of the inflorescence.

Such being the normal shedding of flowers and young fruits with Alphonso mangoes grown at Ratnagiri and the influence upon it of bagging the flowers and of spraying with various materials, the next point is to determine the effect upon it of the two agents which have been charged with being responsible chiefly for the damage,—namely the *jassid* hoppers (*Idiocerus* sp.) and the mildew, which are so frequently found in connection with it. The experiments made have dealt chiefly with the effect on the shedding, of excluding these agents by spraying with materials as above mentioned which exclude their activity. Before describing the results of these experiments, a brief account of these two agents may be given.

* Only 19 flowerheads were examined in this case.

PLATE III.



Mango Jassid hopper (*Idiocerus niveosparsus*).

Mango jassid hopper.

The mango hoppers have been considered as a very serious pest of mangoes and the various species of *Idiocerus* have been several times described, the latest account being given by Afzal Husain and Pruthi.* These authors only give an account of two species of these hoppers, namely, *Idiocerus atkinsoni* Leth and *Idiocerus clypealis* Leth. In a note to the paper referred to, Kunhi Kannan has indicated that he has worked out the life history of the third species known to be present on the mango tree, namely *Idiocerus niveosparsus* and this last has been found to be the most frequent and apparently the most injurious at Ratnagiri. The notes which follow refer to this last named species.

The method of studying these insects under controlled conditions adopted, was to enclose a fresh mango flower shoot in a small glass jar. A cloth bag open at both ends was prepared and carefully tied round the mouth of the jar at one end. The flower shoot was then kept in the arrangement thus made, the other end of the bag being tightly tied round the branch producing the flower shoot. Thus the flower shoot is completely enclosed in the jar. A fertilized female adult hopper with a swollen abdomen was caught and enclosed in the jar for one night and then removed. The development of the eggs was then carefully watched from day to day.

The following notes represent the life history as thus worked out at Ratnagiri, which differs markedly from that found by Afzal Husain in the Punjab.

The eggs are laid in the mid rib of the tender leaves generally on the lower surface, or in the axis of the flowerhead. They are almost cigarshaped tapering at one end and slightly round at the other. They are about 1 millimeter in length. They hatch in five to six days. The nymphs when hatched are also about 1 millimeter in length. The adult at Ratnagiri comes out after 10 to 11 days. Thus the whole life history from the laying of the eggs to the emergence of the adult hopper is sixteen to seventeen days.

Two adults enclosed in the way above described laid fourteen and sixteen eggs respectively in one night. They have been noticed to breed at any time of the year provided there is suitable food material for the nymphs in the form of flowerheads or tender vegetative shoots.

The adults of *Idiocerus niveosparsus* are always found on the *leaves* of mango trees except at the flowering season when they mostly rest on the flower shoots. The same is true of those of *Idiocerus clypealis*. But the adults of *I. atkinsoni* are mostly found on the stems by day and on the under surfaces of leaves at night. *Idiocerus niveosparsus* is sometimes also seen on leaves of various species of citrus fruits. Adults of all the species enclosed in a cage on a mango stem without any foliage inside are found to die within a day, while those with foliage inside are able to live for a long time. This shows that the adults feed on the leaves when there are no flowerheads. The hoppers are very susceptible to high temperatures, and

* Proceedings of the Fifth Entomological Meeting, Pusa, p. 252 (Calcutta 1924).

die very quickly if kept in a tube in the sun. If kept in a cool place, they are able to live for a long period. Gardens thickly planted and with shade all over, harbour very large numbers of them and are thus more affected.

During the flowering season both adults and nymphs are found, when present at all, in very large numbers on the inflorescences, and, in fact, it appears as if the opening of the flowers attracts the adult hoppers from the leafy portions of the tree. Once there, they suck vigorously at the stalks of the inflorescence, both the rachis and the stalks of individual flowers. It is natural that by far the greatest damage is done by the nymphs, for these are very numerous on the flower head during the season, as will be seen from the figures given above as to the number of eggs laid per hopper.

The number of the hoppers present is very variable. In 1925-26, no extensive appearence of these insects occurred at any time during the season from February when the observations began to the end of the flowering. In 1926-27, there were very few during the first two months of the flowering season, namely November and December. Then, in January a very large number appeared at the time of the second flush of flowers. Thereafter they were very much reduced in numbers and were little visible during the third flush of the season. It thus appears that there is considerable variation in the prevalence of the insect from season to season, and also from period to period within each season. If this insect is the dominant agent in causing flower and fruit shedding, the proportion of such shedding should be very widely different in different parts of the same season.

We may, in fact, compare the loss at each stage on twenty flowerheads in the first and on ten flowerheads in the second flush of 1926-27. The first flush took place in the absence of hoppers, or, at most, their presence to a very small extent. At the time of the second flush, they were present in abundance while, fortunately, there was very ittle mildew. The difference between the results with the first and second flush may, therefore, be put down largely to the hoppers. The figures obtained were as follows :—

Proportion of shed flowers, 1926-27.

—	1st flush (Hoppers absent)	2nd flush (Hoppers present)
Complete flowers produced and examined	2,151	1,264
Proportion—	Per cent.	Per cent.
a. shed before fertilisation	53·5	62·6
b. shed after fertilisation	46·3	37·2
c. of ripened mature fruit	0·28	0·24

There is, therefore, remarkably little difference in the total proportion of flowers and young fruits shed due to the presence of the hoppers. In their presence, the proportion shed before fertilization is greater, but the actual proportion of fruits ripened is only about 14 per cent. less, which hardly suggests that these insects, at Ratnagiri at any rate, are the principal agent in causing loss of flowers and fruit.

Direct experiments were, however, undertaken to determine the effect of the insects, by introducing them into bagged flower heads, as small nymphs. The number thus introduced per flower head has been shown on page 227 and varied from 100 to 200 in 1925-26, to 225 to 275 in 1926-27. When they become adult they were allowed to escape. The results on the flower heads so treated (ten in number) were compared with a similar number bagged but not inoculated, with the following results :—

TABLE XV.

Effect of inoculating flower heads with hoppers (Bagged heads).

—	Flowers shed per 100 complete flowers formed		Ripe fruits per 100 complete flowers
	Shed before fertilisation	Shed after fertilisation	
1925-26	Per cent.	Per cent.	
1. Inoculated with hoppers	61·9	38·1	No fruits.
2. Free from hoppers	54·0	45·8	0·22 per cent.
1926-27			
First flush			
1. Inoculated with hoppers	90·1	9·9	No fruits.
2. Free from hoppers	87·5	12·3	0·15 per cent.
Second flush			
1. Inoculated with hoppers	80·3	19·7	No fruits.
2. Free from hoppers	82·3	17·5	0·17 per cent.
Third flush			
1. Inoculated with hoppers	74·6	25·4	No fruits.
2. Free from hoppers	76·3	23·5	0·18 per cent.

These figures, resulting from intensive inoculation with the hopper, show the possible effect of the insect in a really serious attack. The inoculations were usually made by introducing from five to fifty nymphs per flowerhead at the same time, a fresh lot being put in when the previous supply had all become adult. It may, therefore, be taken as proved that the insect *can* be the cause of the complete loss of the mango crop. How far it actually does cause such loss in practice in the mango growing area at Ratnagiri has already been studied above and will be considered further in connection with the treatments designed to exclude its influence on a large scale.

Flower mildew of the mango.

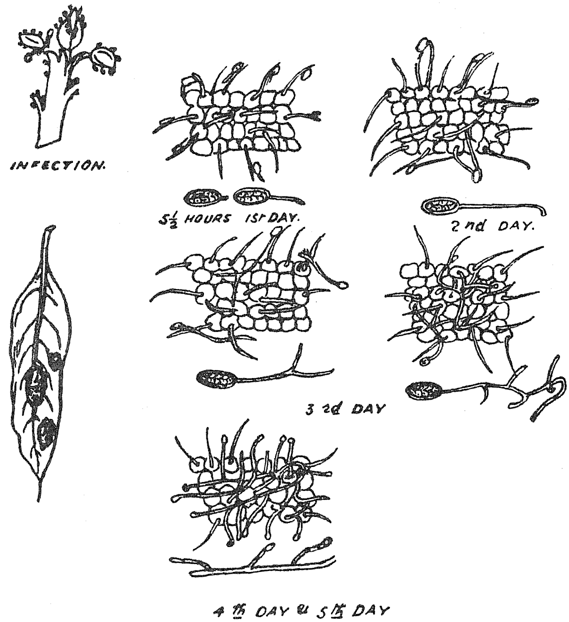
The possible importance of any mildew or other fungus in the falling of the mango flowers and fruits does not seem to have been fully recognised by previous workers on the subject. The fact that a mildew does occur on the mango inflorescence was noted in 1921 in Mysore [1] and Patwardhan remarks that the mildew *Erysiphe cichoracearum* did not appear in a mango garden in Thana (Bombay) in 1925.[2] By this it is assumed that this fungus had been detected on the flower heads in other cases. The fact that a fungus, resembling a mildew, is often found on fallen mango flowers seems, however, to be generally known and it is in fact prominent on many inflorescences especially during the latter part of the flowering season.

It is not proposed to present here a technical description of the fungus, which was identified by the Mycological authorities at Poona as *Erysiphe cichoracearum* D. C. If this identification is correct, it is the common mildew of tobacco, cucurbits and malvaceous vegetables in Western India. As it occurs on the mango inflorescence, the powdery incrustation shows innumerable hyaline oval spores, sticking to each other and forming clusters (Plate IV). A transverse section of the affected part shows these spores to be borne at the tips of conidiophores which are divided by cross septa into two or three cells below the spore. The mycelium is quite superficial and none is found in the internal tissues.

For studying the different stages of the fungus, artificial inoculations were made. Some flowerheads were enclosed in muslin bags and thoroughly washed with disinfecting solution of mercuric perchloride (1 in 1,000) which was immediately washed off with distilled water. Then flowerheads affected with mildew were brought and shaken violently near the disinfected flowerheads so that the spores from the former were blown in profusion to the latter. The bags were immediately closed. Then scrapings were taken from the inoculated flowerheads twice every day and examined under the microscope. The life history was found to be as follows :—

The spores when blown off from an affected area easily stick to the hairy unopened flowers near the tip of the inflorescence. These germinate within five to seven hours.

[1] *Journal Mysore Agri. and Expt. Union*, Vol. III, No. I (1921).
[2] Patwardhan, G. B. *Ann. Rept. Agri. Dept. Bombay*, 1924-25, Page 157 (1924).



The flower mildew of the Mango (*Erysiphe* sp.).

The germ tube grows and within two days begins to branch and form mycelium. The mycelium then spreads profusely on the epidermal cells, which are killed by the feeding of the fungus and thus turn brown. On the fourth day several vertical bodies begin to appear from the mycelium. These are sporophores. On the fifth day, the mycelium becomes so profuse and so many sporophores with oval mature spores are produced that the whole of the affected surface puts on the characteristic white appearance of the powdery mildew. Thus the life history from spore to spore is about five days. The attack generally begins from the buds at the tip of the inflorescence, as these being more hairy very easily catch the spores. Then it gradually extends on the flowerhead. Mildew also appears naturally on the tender vegetative shoots of the mango but the life history there is somewhat longer being about nine days.

In order to find out other hosts of the mildew, inoculations were also tried on *Bhendi* and *Guvar* leaves, but the mildew did not appear at all. The mildew spores retain their vitality for four to five days only and then shrivel up. If kept in the sun without any moisture, they shrivel up within four or five hours.

This mildew has been present on the inflorescences at Ratnagiri both in 1925-26 and 1926-27, but in both years it was not found on the first flush of flowers, but gradually increased in amount as the season progressed. In 1926-27 when very closed detailed observations were made, it may be said that it was completely absent from the flowers until January 1927 and even from that time until February it was present only in very small amount. The third flush in February and March was, however, very much attacked with it, and the variation in intensity noticed enables us to get some idea of the damage which it does. We may, in fact, compare the loss in the first flush (when neither hoppers nor mildew were present to any appreciable extent) with that in the third flush when mildew was very much in evidence, and hoppers had almost disappeared. Twenty flowerheads were investigated in the former, and ten in the latter flush. The results were as follows :—

—	Proportion of shed flowers	
	1st Flush	2nd Flush
	(Mildew absent)	(Mildew present)
Complete flowers produced and examined	2,151	852
Proportion—	Per cent.	Per cent.
a. shed before fertilisation	53·5	61·5
b. shed after fertilisation	46·3	38·4
c. of ripened mature fruit	0·28	0·12

Here we have, therefore, some, though not conclusive, evidence of the part which mildew takes in the loss of flowers and young fruits, for the proportion of fruits ripened per 10,000 flowers is reduced from 28 to 12 or by 43 per cent. The stage at which this increased loss takes place is better shown by the following figures, which

indicates the proportion of the *remaining* flowers and fruits after the previous loss has taken place which shed at the succeeding stage :—

—	1st Flush (Mildew absent)	2nd Flush (Mildew present)
Complete flowers produced and examined . . .	2,151	852
Proportion—	Per cent.	Per cent.
a. of complete flower shed before fertilisation .	53·5	61·5
b. of fertilised flowers shed before fruit is 0·4 cm. in diameter.	88·8	95·1
c. of fruit 0·4 cm. in diameter shed before 1·5 cm. in diameter.	77·0	75·0
d. of fruit 1·5 cm. in diameter shed before maturity	77·0	75·0

Thus it is quite clear that the loss due to mildew affects the flowers before fertilisation, and the fruits in the youngest stages. If these latter reach 0·4 cm. in diameter the mildew can do them no further harm. In the early stages it does seem to be a very important agent in increasing the loss of flowers and young fruits and so seems of great importance.

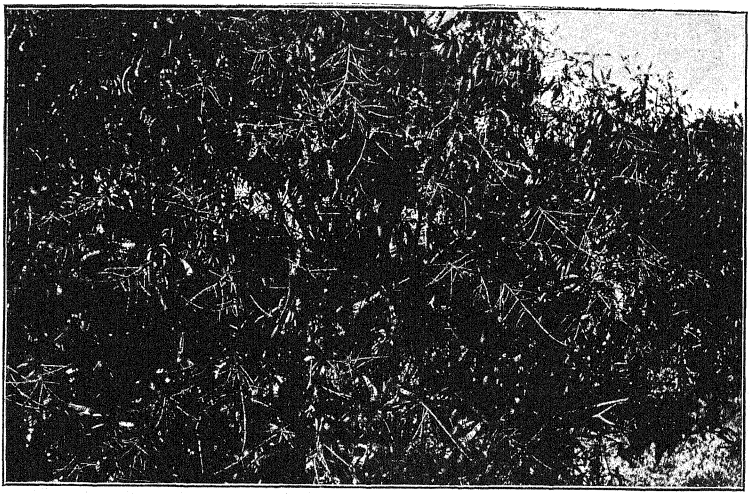
Direct experiments were also undertaken to determine the effect of the mildew, when introduced into bagged flowerheads, as described on page 227. The results on the flowerheads so treated (ten in number in 1925-26 and 40 in number in 1926-27) were compared with a similar number bagged but not inoculated, with the following results.

TABLE XVI.

Effect of inoculating flowerheads with mildew (Bagged heads).

—	Flowers shed per 100 complete flowers formed.		Ripe Fruits per 100 complete flowers.
	Shed before fertilisation	Shed after fertilisation	
1925-26	Per cent.	Per cent.	Per cent.
1. Inocluted with mildew	66·1	33·8	0·10
2. Not inoculated	54·0	45·8	0·22
1926-27 *First flush*			
1. Inoculated with mildew	87·9	12·1	No fruits.
2. Not inoculated	87·5	12·3	0·15
Second flush.			
1. Inoculated with mildew	85·6	14·2	0·12
2. Not inoculated	82·3	17·5	0·17
Third flush.			
1. Inoculated with mildew	91·5	8·5	No fruits.
2. Not inoculated	76·3	23·5	0·18

PLATE V.



Appearance of inflorescences with bad attack of the mango *jassid* hopper.

The uninoculated flower heads were not always entirely free from mildew, but they always, of course, had much less of the fungus present than the inoculated flower heads. In the first flush of 1926-27, mildew was entirely absent and in the second flush it was only present in very small amount on the non-inoculated heads.

These figures, resulting from intensive inoculation with the mildew, show the *possible* effect of the fungus in a really serious attack. Under these circumstances, it will be seen that, even excluding other influences causing loss of fruits, the mildew was capable of completely destroying the crop,—as occurred in the first and third flushes of 1925-27, or in other cases of reducing it by one third (second flush of 1926-27), or by more than one half (1925-26) in two separate cases.

Effect of insecticidal and fungicidal treatment.

The methods designed to keep off the attacks of the *jassid* hopper and the mildew above described have been already detailed (Page 226). They consisted of repeated sprayings with either Fish oil soap solution (against the hopper) or Bordeaux mixture (against the mildew) or with a mixture of both these.

The efficiency of these treatments was not complete. So far as the hoppers were concerned each spray with the fish oil soap solution completely destroyed any nymphs of the *jassid* hopper which were on the inflorescences at the time and either killed or drove away the adults which were present. Within three or four days, however,—when the insect was abundant,—a few nymphs were again noticed. This number tended to increase, and before the time of the next spraying,—which occurred during the second flush at intervals of from eight to fifteen days, the nymphs were again fairly numerous on the flower heads. Naturally, as the inflorescence becomes more mature, it becomes more and more difficult for the insect to lay its eggs in the *rachis* and in the branches of the inflorescence, and so if spraying is vigorously done, repeatedly, when the flower heads are young, the number of nymphs ultimately found on the head is materially reduced. But, though the treatment was repeated so often, the flower heads were not maintained anything like free of the *jassid* hoppers during the flowering.

A similar position is found with regard to the mildew. The fungus attacks chiefly, if not entirely, the very young parts of the flower head at the tip of each branch of the inflorescence. If it is then sprayed with Bordeaux mixture, the mildew is killed, but rapidly reappears on portions of the inflorescences which are subsequently formed. So that fresh spraying is really required at very short intervals. So that the new growth may be protected before the mildew has time to attack it. This is not, of course, entirely possible and repeated sprayings at intervals of from seven to fifteen days is the best that is practicable. It must be recognised, however, that the treatment does not entirely prevent mildew, but it certainly reduces it very largely.

The actual results of these treatments can be best judged by the figures obtained with tre ted flower heads in both 1925-26 and 1926-27. In the first year no hoppers

were found and hence the comparison in that year is as to the effectiveness of the treatments in preventing loss by mildew, or by other unrecognised causes which accompany it.

TABLE XVII.

Effect of treatments in presence of mildew only, 1925-26.

—	FLOWERS SHED PER 100 COMPLETE FLOWERS FORMED		Ripe fruits per 100 complete flowers
	Shed before fertilisation	Shed after fertilisation	
	Per cent.	Per cent.	Per cent.
1. Without treatment	38·4	60·8	0·77
2. Sprayed with Bordeaux mixture	42·9	56·2	0·93
3. Sprayed with Fish oil soap solution	48·8	50·7	0·47
4. Sprayed with combined spray	49·1	50·6	0·23

When, therefore, these sprays are used in the presence of mildew, they all cause an increased loss of shedding before fertilisation and this would perhaps not be unexpected. The loss by shedding after fertilization proved itself greater wherever Fish oil soap solution was used. Taking the percentage of loss on the *actual flowers* fertilised, the figures of shedding were as follows :—

	Per cent.
1. Without treatment	98·7
2. With Bordeaux mixture	98·4
3. With Fish oil soap solution	99·2
4. With combined spray	99·4

The difference is not, however, very great, and the real cause of the difference in the number of fruits ripened is the difference in the loss before fertilization—except that the untreated flower heads, which lost relatively less before fertilization, had a larger loss after this had taken place.

In the second year (1926-27) there was practically no mildew on the second flush and hence we have merely to consider the effect of the spraying treatments in the presence of *Jassid* hoppers. This is shown in the following figures ;—

TABLE XVIII.

Effect of treatments in presence of hoppers only, 1926-27.

—	FLOWERS SHED PER 100 COMPLETE FLOWERS FORMED		Ripe fruits per 100 complete flowers
	Shed before fertilisation	Shed after fertilisation	
	Per cent.	Per cent.	Per cent.
1. Without treatment	62·6	37·2	0·24
2. Sprayed with Bordeaux mixture	72·5	27·3	0·24
3. Sprayed with Fish oil soap solution	69·5	30·1	0·39
4. Sprayed with combined spray	74·7	25·0	0·23

Here, therefore, when these sprays are used in presence of hoppers only, that is to say, when the insects are *partially* suppressed during the flowering—the effect of all the sprays still shows an increased shedding before fertilisation. It would seem, in fact, that all the sprays when used with flowers which have been weakened by the insects, cause a greater number to drop off before they are fertilised.

After fertilisation there is less shedding wherever the material (Fish oil soap solution) which is supposed to check the hoppers is used, as is shown by taking the percentage of loss of actual flowers fertilised as follows :—

	Per cent.
1. Without treatment	99·4
2. With Bordeaux mixture	99·1
3. With Fish oil soap solution	98·7
4. With combined spray	98·7

The increased shedding of the unfertilized flowers more than neutralises with the combined spray, the advantage gained with those fertilized and the young fruits. With the Fish oil soap solution only, the difference shows quite clearly in a considerable increase in the number of fruits ripening.

We can now consider the effect of the treatments in the presence of mildew only by studying the third flush of 1926-27, for at this time the hoppers had practically disappeared, while mildew was very severe. Under these circumstances, the following figures were obtained.

TABLE XIX.

Effect of treatments in presence of mildew only, 1926-27.

—	FLOWERS SHED PER 100 COMPLETE FLOWERS FORMED		Ripe fruits per 100 complete flowers
	Shed before fertilisation	Shed after fertilisation	
	Per cent.	Per cent.	Per cent.
1. Without treatment	61·5	38·4	0·12
2. Sprayed with Bordeaux mixture . . .	62·1	37·5	0·40
3. Sprayed with Fish oil soap solution . .	57·1	42·7	0·23
4. Sprayed with combined spray . . .	62·5	37·5	No Fruits.

Under these conditions of high mildew attack, without the presence of hoppers, the treatments (except that with Fish oil soap solution, which cannot at present be accounted for) seem to have had little effect on the loss before fertilisation. If any thing, the amount of loss at this stage was increased as in the previous cases.

After fertilisation, there is distinctly less shedding with the treatment with Bordeaux mixture, which was used specifically to check the mildew, as is shown by taking the percentage of loss of *actual flowers fertilised,* as follows :—

	Per cent.
1. Without treatment	99·7
2. With Bordeaux mixture	98·9
3. With Fish oil soap solution	99·5
4. With combined spray	100·0

The checking of the fungus attack, when this latter was very active, has led in fact to raising the proportion of fertilised flowers which come to maturity by a substantial amount. The number has been raised to three times that in the untreated flowers heads. The fish oil soap solution, whether alone or as a combined spray, has been of much less use, and in the latter case the *whole* of the fertilised flowers fell without forming fruits.

These figures show very clearly the very important part played by mildew, when it is present, in causing the fall of flowers, and particularly of fertilised flowers and very young fruits. But it is equally obvious that it is not, by any means, the chief cause of the fall even of fertilised flowers and young fruits,—and while it may reduce the crop from a flush to one third its normal amount, there is an enormous shedding to account for, independently of any mildew attack.

But this extra loss due to mildew is of very great importance, and may obviously make all the difference between a profitable flush and one which is a financial failure.

So far the treatments described were applied to a number of flowerheads which were separately kept under observation. But at the same time, the treatment with Fish oil soap solution was applied to whole trees,—half the tree in each case being kept unsprayed. We can thus compare the number of ripened fruits per hundred flowerheads on the two halves of the same tree, and thus get a reliable measure of the effectiveness of the treatment. The results were as follows, the trees being sprayed as frequently and at the same times as described on page 226.

TABLE XX.

Effect of spraying whole trees on fruit ripening.

—	Number of flower heads on half tree	1926-27		
		Number of fruits obtained on half tree	Number of of fruits per 100 flower heads	Percentage increase by treatment
1st tree.				
1. Unsprayed	956	197	20·6	..
2. Sprayed with Fish oil soap solution .	588	152	25·8	25·4
2nd tree.				
1. Unsprayed	784	225	28·7	..
2. Sprayed with Fish oil soap solution .	430	141	32·8	14·3

Other tests made by spraying some trees in a garden and comparing them with unsprayed trees in the same garden gave an increase of fruits 31·9 per cent. and 25·0 per cent., respectively. But too much stress should not be laid on these figures, as trees differ so much in their individual capacity to bear. Enough has been found, however, to show that by spraying in the manner suggested through the hopper season at Ratnagiri, the number of ripened fruits can be increased by from 14 to 25 per cent. and possibly by more than this amount.

INFLUENCE OF OTHER FACTORS ON MANGO FLOWER AND FRUIT SHEDDING.

As already stated, the popular idea is that the loss of mango flowers and young fruits is much increased by cloudy, wet, or dewy weather during the flowering season. Hence an attempt was made to see how the fall of flowers and young fruits was affected by excluding any rain or dew which might fall on the inflorescences. To do this, five flower heads during 1925-26, and ten flower heads during 1926-27 were protected above with a glass plate, so that any moisture falling on them from above was excluded.

Only the records for 1926-27 have been kept completely. In this year a full record of the rain and dew was maintained. Dew was common in February and March, but no rain fell throughout the flowering season. The performance of the protected flowerheads as compared with controls either on the same trees or in the immediate neighbourhood was as follows :—

TABLE XXI.

Shedding of flowers and young fruits protected from rain and dew.

—	Number of complete flowers	Flowers shed per 100 complete flowers formed		Ripe fruits per 100 complete flowers
		Shed before fertilisation	Shed after fertilisation	
		Per cent.	Per cent.	Per cent.
1. Without protection	2,151	53·5	46·3	0·28
2. Protected with glass covers	2,137	69·8	29·9	0·28

Thus, from these figures, it will be seen that the final production of ripe fruits was not altered by the protection given. The presence of the cover seemed to reduce the number of *fertilised* flowers and young fruits which were shed, but, on the other hand, tended to increase the shedding of the flowers before fertilisation. There is, however, no evidence that under the conditions of the last season, such protection as that given was of any great advantage. This is in agreement with results obtained by Popenoe[1] in Florida.

The only other cause of the variation in the shedding which has been suggested is the want of assimilated plant food and possibly also of water, and attempts have been made in both the seasons under record to ascertain whether the application of irrigation during the flowering season to trees, or the addition of concentrated manures applied in trenches round the trees, made a very substantial difference to the yield of fruits per 100 flower heads. The results in both cases are, the author feels, vitiated because of the very large variation from tree to tree in all cases. It is true that, on the average, each of these treatments, with irrigation or with concentrated manures, raises the number of fruits produced per 100 flower heads. Thus, in 1926-27, taking the record of three trees, irrigation raised the number of fruits per 100 flower heads

[1] Popenoe, W. Manual of Tropical and Sub-Tropical Fruits, 1920.

from 29 to 37, but the actual number of fruits per 100 flower heads were in each of the three cases

1. Irrigated trees	45, 21 and 44
2. Unirrigated trees	41, 20 and 27

So that it is very doubtful whether the difference is due to the irrigation at all. Similar vitiation of the results has been the case in those trees where concentrated manures have been used, and we are compelled to leave further investigation of the matter to the next year.

General conclusions.

The author feels that the results of this investigation, so far as they have gone, have emphasised the very great loss even of complete flowers, which normally takes place in mango flowering. That loss, including the cases where the flowers fall before fertilisation and those where young fruits are shed, amounts normally, with the Alphonso variety of the mangoes at Ratnagiri, to over 99 per cent. of the complete flowers formed. In some years, as in 1926-27, the loss was in all cases substantially over 99·5 per cent.

So far as almost the whole of this loss is concerned, the investigations made have so far not revealed any cause for the falling of the flowers and fruits. Only a very small proportion of the flowers in certain flushes, at any rate, showed any recognisable outward symptoms which would have suggested that they were likely to fall. These recognisable causes were mildew and certain black spots on the flower and fruit stalks and on the fruits, the nature of which was not identified. But both these classes of symptoms were present in so small a proportion of cases, that it is evident that they were very minor elements in causing flower and fruit shedding in the mango.

The cause of by far the largest proportion of the loss of mango flowers and young fruits, therefore, remains a mystery. But there are two clear causes which are able to affect very materially the quantity of fruits, small though it be, which actually ripen. So far as the experiments show, the presence or absence of rain or dew is not one of these, though this matter still needs further investigation. But the well known *Jassid* hopper, the chief species of which at Ratnagiri is *Idiocerus niveosparsus*, and the mango flower mildew, which belongs to a form of *Erysiphe* which has not been fully studied, both affect very materially the proportion of complete flowers which ripen into fruits.

At Ratnagiri, however, the first flush of flowers in November and December seems normally free or nearly free from both these enemies, the second flush in January and early February usually has abundance of hoppers and a small amount of mildew, while in the third flush in late February and March, the hoppers are much less abundant, but the mildew tends to get worse and worse. In some years, as in 1925-26, the hoppers were very rare throughout the season.

Any attempt to check these two enemies by spraying, even repeatedly and at short intervals, has been only very partially effective in keeping the flower heads free of them. The reinfection of inflorescences which have been cleared of hoppers by fish oil soap solution was almost immediate and as the greater part of the damage is done by the nymphs, they were able to affect the flower head materially before the next spraying took place. In the case of mildew, the attack takes place by preference on the portions of the inflorescences as they appear, that is to say, on the youngest portion. The result is the relative inefficiency of the spraying treatment, even frequently repeated against this also.

But three things seem clear from the study of treatments by spraying. The first is that all of them cause, whether the pests and blights are present or not, an increased loss of unfertilised flowers, though they may lead to a reduction in the amount of fall in flowers after fertilisation. In the absence of disease, the total effect of the sprayings is negligible.

The second is that the spraying with Bordeaux mixture has been effective in increasing the percentage of success in ripe fruits when mildew is present by 21 per cent. in 1925-26 and by 230 per cent. in 1926-27. In presence of mildew (hoppers being absent), spraying with fish oil soap solution seemed distinctly harmful in 1925-26, while the result was doubtful in 1926-27.

The third result is that, in presence of hoppers spraying with fish oil soap solution increased, in the flower heads under detailed examination, the yield of ripe fruits by 62 per cent. in 1926-27. A combined spray of Bordeaux mixture and Fish oil soap solution was not effective even against hoppers.

The work will be continued in the next two seasons, with the chief object of, on the one hand, finding an effective method of controlling the hoppers and mildew under the conditions of attack which have been described, and, on the other, of trying to trace further the cause of some at any rate of the loss of complete flowers which leads, at present, even under the most favourable circumstances to a shedding over 99 per cent. in the principal commercial variety of mango at Ratnagiri.

Bibliography.

1. Popenoe, W. The Pollination of Mango. *U. S. Dept. Agri. Bull.* 542 (1917).
2. Popenoe, W. Manual of Tropical and Sub Tropical Fruits. New York. 1920.
3. McMurram, S. M. The Anthracnose of the mango in Florida. *U. S. Dept. Agri. Bull.* 52. (1914).
4. Ballard, E. Mango Hopper Control Experiments. *Agri. Jour. India*, Vol. X (1915).
5. Burns, W., and Prayag, S. H. The Book of the Mango. *Bombay Department of Agriculture, Bull. 103* (1920).
6. Burns, W., and Prayag, S. H. Notes on the Inflorescence and Flower of the Mango tree. *Poona Agri. College Magazine*, Vol. II (1911) page 226.

7. HUSAIN, M. A., AND PRUTHI, H. S. Some Experiments to control Mango Hoppers. *Report of the Proceedings of the Fourth Entomological Meeting, Pusa* (Calcutta 1921).
8. Note on Mango Hopper and Mildew. *Journal Mysore Agri. and Expt. Union,* Vol. III (Bangalore 1921).
9. JIVAN RAO, P. S. Pollen Sterility in relation to Vegetative Propagation. *Jour. Madras Agri. Students' Union,* Vol. XI, Nos. 9 and 10 (Coimbatore 1923).
10. Mango Hopper Pest. *Agri. Jour. India,* Vol. XV, p. 222, (1920).

APPENDIX I.

The composition of forty mango inflorescences in 1925-26.

Serial No.	Total No. of flowers	Male flowers	Complete flowers	Percentage of complete flowers
1 . . .	550	313	237	43·09
2 . . .	1,147	919	228	19·7
3 . . .	2,823	2,432	391	14·5
4 . . .	600	344	256	42·66
5 . . .	492	432	60	12·13
6 . . .	3,549	3,307	242	6·81
7 . . .	1,195	991	204	17·07
8 . . .	1,186	957	229	19·30
9 . . .	338	309	29	8·58
10 . . .	789	593	196	24·84
11 . . .	3,129	2,867	262	8·37
12 . . .	1,555	1,015	540	34·72
13 . . .	508	327	180	35·43
14 . . .	2,540	2,470	70	2·75
15 . . .	2,080	1,975	105	5·04
16 . . .	970	734	236	24·33
17 . . .	56	25	31	55·35
18 . . .	369	304	65	17·04
19 . . .	354	190	164	46·32
20 . . .	147	144	3	2·04
21 . . .	151	98	53	35·08
22 . . .	206	138	68	33·00
23 . . .	834	565	269	32·13

The composition of forty mango inflorescences in 1925-26—contd.

Serial No.	Total No. of flowers	Male flowers	Complete flowers	Percentage of complete flowers
24 . . .	282	240	42	14·80
25 . . .	279	161	118	42·29
26 . . .	971	855	116	11·9
27 . . .	502	249	153	30·47
28 . . .	1,599	945	654	40·9
29 . . .	518	233	285	55·01
30 . . .	2,454	1,838	616	25·0
31 . . .	573	499	74	12·09
32 . . .	1,584	1,138	466	29·4
33 . . .	481	415	66	13·74
34 . . .	959	868	91	8·48
35 . . .	448	298	150	33·48
36 . . .	20	15	5	25·0
37 . . .	917	829	88	9·59
38 . . .	2,096	1,591	505	24·09
39 . . .	663	402	261	30·9
40 . . .	1,465	1,046	419	28·60